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16. ABSTRACT

The objective of this study was to compare the results between two previous indoor air PAH monitoring studies conducted by EPA in 1984 and 1987. Both of the previous studies were pilot studies involving ambient and indoor air monitoring at a small number of residences in Columbus, Ohio. The objectives of these studies were to characterize the ranges of selected PAH and nitrogen heterocyclic compounds in the indoor air and to evaluate contributions of various indoor combustion sources to the indoor PAH concentration levels.

This current study compared the results between the 1984 and 1987 studies, and where the results were consistent, the data from the two studies were combined to produce more precise statistical estimates of concentration level ranges and estimates of the contributions of different indoor combustion sources to indoor PAH levels.

Results between the two studies were found to be consistent for all compounds except quinoline and isoquinoline. Excessive breakthrough in the PUF vapor traps used in the 1984 study resulted in lower measured concentration levels than those measured for the 1987 study using an XAD-4 resin vapor trap. The combined study data showed that cigarette smoking and gas heating systems were the two biggest contributors to indoor PAH concentration levels.

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by

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate environmental problems, to support regulatory actions by developing an in-depth understanding of the nature of processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Atmospheric Research and Exposure Assessmment Laboratory, Research Triangle Park, North Carolina, has responsibility for assessment of environmental monitoring technology and systems for air, implementation of agency-wide quality assurance programs for air pollution measurement systems, and supplying technical support to other groups in the Agency, including the Office of Air and Radiation, the Office of Toxic Substances, and the Office of Solid Waste.

The determination of human exposure to toxic organic compounds is an area of increasing significance to EPA. This statistical comparison of results obtained from two indoor air pilot studies provides an important step toward measurement of, and understanding, the extent of human exposure to these organic pollutants.

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ABSTRACT

The objective of this study was to compare the results between two previous indoor air PAH monitoring studies conducted by EPA in 1984 and 1987. Both of the previous studies were pilot studies involving ambient and indoor air monitoring at a small number of residences in Columbus, Ohio. The objectives of these studies were to characterize ranges of selected PAH and nitrogen heterocyclic compounds in the indoor air and to evaluate contributions of various indoor combustion sources to the indoor PAH concentration levels. The 1984 study used an EPA medium volume air sampler equipped with a quartz fiber filter and a PUF vapor trap while the 1987 study used a new prototype air sampler equipped with a quartz fiber filter and an XAD-4 resin vapor trap.

This current study compared the results between the 1984 and 1987 studies to determine whether the results are consistent. Where the results were found to be consistent, the data from the two studies were combined to produce more precise statistical estimates of concentration level ranges and more precise estimates of the contributions of different indoor combustion sources to indoor PAH levels.

Concentration level ranges were found to be consistent between the 1984 and 1987 studies for all compounds except quinoline and isoquinoline. For quinoline and isoquinoline, excessive breakthrough in the PUF vapor traps used in the 1984 study resulted in lower measured concentration levels than found in the 1987 study. The estimated PAH contributions of indoor combustion sources were also found to be consistent between the studies for all compounds except quinoline and isoquinoline. The data from the 1984 and 1987 study were therefore combined and a new model was fit to the combined data. From the combined data, cigarette smoking and gas heating systems were found to be the greatest contributors to indoor PAH concentration levels. However, the data indicate that the effects of gas heating systems and gas cooking appliances are not known with as much certainty as are the effects of cigarette smoking. Finally, data from the 1984 study were found to be consistent with models previously developed from the 1987 data for predicting levels of PAH target compounds from measured levels of potential PAH marker compounds.

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SECTION 1

INTRODUCTION

The EPA as part of its indoor air methods development program, has previously conducted two separate small studies of indoor air levels of polynuclear aromatic hydrocarbon (PAH) compounds. The first study was conducted in 1984 and was titled "Pilot Study of Sampling and Analysis for Polynuclear Aromatic Compounds in Indoor Air" (1). The second study was conducted in 1987 and was titled "Field Evaluation of Sampling and Analysis for Organic Pollutants in Indoor Air" (2). Both studies involved monitoring of PAH and nitro-PAH compounds in ambient and indoor air at a small number of homes in Columbus, Ohio. The objectives of both studies were to evaluate sampling and analysis methodology, to characterize typical concentration levels of PAH and related compounds found in the indoor air, and to investigate the individual contributions of different indoor combustion sources on PAH levels in the home.

Although both studies were similar, there were a number of differences between the two studies with respect to their design and the experimental factors investigated. In addition, the 1987 study investigated a number of questions not addressed in the 1984 study. The objective here, therefore, was to compare the results of the 1984 and 1987 studies, and to use the data from the 1984 study to evaluate some of the key findings of the 1987 study.

The compounds considered in this analysis include PAH and nitrogen heterocyclic compounds. Because in the 1984 study the three 8-hour samples were pooled for each home to achieve detectable levels of NO_2-PAH there were not sufficient data available to compare with the 1987 study. Furthermore, the 1984 NO_2-PAH measurements included the bedroom sampling period which was known to have lower concentration levels, and 1987 NO_2-PAH measurements did not include the bedtime sampling period. Therefore, comparison of NO_2-PAH data obtained from 1984 and 1987 would not be appropriate, and the NO_2-PAH data were not included in this study.

Here, ranges of the concentration levels for the measured compounds are compared across studies. Also, the estimated pollutant contributions of various indoor combustion sources are compared. Whenever the results are found to be consistent, the data from the two studies are pooled to produce an updated set of results based on the combined data from both studies. Key questions addressed in this study include:

1. Are the observed ranges of concentration levels of PAH and nitrogen-heterocyclic compounds similar across studies? Are there differences in concentration levels due to differences in the degree of vapor trap breakthrough experienced between the two studies?

2. Are the estimated contributions of gas heating systems, gas cooking appliances, and cigarette smoking to the PAH concentrations in indoor air consistent between the 1984 and 1987 studies? In particular, results from the 1987 study indicated that use of electric cooking appliances contribute more to the PAH levels than do gas appliances. Do the data from the 1984 study refute or confirm this finding?

3. How well can we predict the levels of various PAH target compounds from the measured levels of potential marker compounds such as pyrene, fluoranthene, and phenanthrene? Are the prediction models developed from the 1984 study data consistent with the prediction models developed from the 1987 study data?

SECTION 2

CONCLUSIONS

The measured concentration ranges were found to be consistent between the 1984 and 1987 studies. For all compounds except quinoline and isoquinoline, there was considerable overlap in the observed concentration ranges. The quinoline and isoquinoline levels found in the 1984 study were much lower due to excessive breakthrough in the polyurethane foam (PUF) vapor traps used in the 1984 study. From these results we conclude that for most target compounds the variability in concentration levels between studies is not significantly greater than ordinary variability due to day-to-day and home-to-home differences. The results for quinoline and isoquinoline indicate that PUF is not as effective as XAD-4 resin for trapping vapors of volatile compounds.

Estimates of the contributions of different indoor combustion sources to the indoor PAH concentration levels were consistent between the two studies for all compounds except quinoline and isoquinoline. The data from the 1984 and 1987 studies were therefore combined and used to obtain more precise estimates of the true contributions of each indoor combustion source. From the combined data we conclude that cigarette smoking and gas heating systems produce the greatest increases in indoor PAH concentration levels. Gas cooking appliances have the least effect. However, the data show there is still considerable uncertainty in the true effects of gas heating systems and gas cooking appliances.

Separate statistical models developed from the 1984 and 1987 data, respectively, for predicting PAH target compound levels from measured levels of potential PAH marker compounds were found to be consistent for all compounds except quinoline and isoquinoline. The data from the 1984 and 1987 studies were therefore combined to obtain new prediction models. Model fitting results from the combined data indicate that the levels of

fluoranthene, pyrene, and phenanthrene show promise as predictors of the levels of the other PAH target compounds. Comparison of the models for each of the three potential marker compounds showed that pyrene is the best marker compound for most of the target compounds investigated.

SECTION 3

RECOMMENDATIONS

The following recommendations are based on the results of this study:

1. The upcoming winter and summer monitoring studies should be used to obtain a better assessment of the true effects of gas heating systems and gas cooking appliances. Cigarette smoking should be eliminated as a factor in these studies. The effects of smoking are already apparent from the data collected from the previous studies. The effect of smoking is so significant that it may mask the true effects of other factors.

2. The air samplers should be placed in only one location within the home rather than placed in different locations for each sampling period. It is likely that the effect of sampler location is really due to sampling period and the residents' activities conducted during each period. By using only one sampling location (living room) in the upcoming winter and summer studies we will be able to determine whether it is, indeed, period of the day that affects the indoor PAH concentration levels.

3. 1-nitropyrene and 2-nitrofluoranthene measurements should be made for each individual sampling period. These compounds must be collected on the same basis as the other compounds if we wish to improve our assessment of the relationships between these compounds and their parent compounds. More data are needed to evaluate the results obtained during the 1987 study.

4. A separate statistical study should be done following the winter and summer studies to compare the data collected during the winter and summer monitoring studies and the 1984 and 1987 studies. This will allow us to better evaluate and validate the statistical models for estimating the contributions of different combustion sources on indoor PAH concentration levels. Updated models can be developed based on the combined data of all the studies. In addition, more data are needed to further evaluate and improve the models for predicting PAH target compound levels from measured levels of potential PAH marker compounds.

SECTION 4

BACKGROUND ON THE 1984 AND 1987 STUDIES

1984 STUDY DESIGN

The first study was conducted in 1984 and was titled "Pilot Study of Sampling and Analysis for Polynuclear Aromatic Compounds in Indoor Air" (1). The objectives of this study were:

1. To evaluate and test generic sampling and analysis methodology for characterizing PAH concentrations in ambient and indoor air
2. To identify sources responsible for variations in the PAH and nitro-PAH concentrations in air, and to quantify the relative contributions of these different sources.

A medium volume EPA sampler was used which had a quartz fiber filter to collect particulate matter and a PUF cartridge to trap vapors. The study investigated the effects of (1) gas heating systems, (2) cigarette smoking, and (3) woodburning fireplaces as possible contributors to indoor levels of PAH and nitro-PAH compounds.

Ten sample homes were selected to have different characteristics relative to the presence of gas versus electric heating systems, presence/absence of woodburning fireplaces in use, and the presence/absence of cigarette smoking in the home.

At each sample home, 8-hour samples were taken at each of three indoor locations within the home: kitchen (7:00 AM to 3:00 PM), living room (3:00 PM to 11:00 PM),and bedroom (11:00 PM - 7:00 AM). A 24-hour ambient air sample was also taken outside the home to coincide with the three 8-hour indoor samples. For each home, the air exchange rate was determined by the decay rate of SF_6 injected into the house. A questionnaire was completed by the residents of each sample home to record residents' activities during the

sampling periods that might have affected concentrations of indoor PAH levels. Among others, the activities recorded include:

- Number of cigarettes smoked during each 8-hour sampling period
- Length of time a woodburning fireplace was in use during sampling
- Type of cooking appliances present in the home.

The 1984 study data which are available for comparison against the 1987 data are given in Figure 4-1. Homes C and F are listed twice since these homes were sampled twice to provide an estimate of day-to-day variability of concentration levels within the same homes. Two of the sample homes (Homes E and J) were omitted from this comparison study because insufficient information was available on cigarette smoking to assess the degree of consistency with results from the 1987 study. The only information we had on these two homes was the total number of cigarettes smoked over all indoor sampling periods combined. In this study, concentration levels and number of cigarettes smoked for each 8-hour sampling period are needed to compare results between the 1984 and 1987 studies.

The 1984 study found that cigarette smoking and type of heating system have the greatest effects on the indoor levels of most PAH, nitrogen heterocyclic compounds, and nitro-PAH compounds. The use of a woodburning fireplace was only weakly correlated with the levels of the target compounds. The study also found that bedroom levels were much lower than levels found in the kitchen and living room. This was likely due to the lack of smoking and cooking activities during the 11:00 PM to 7:00 AM time period.

The results from the 1984 study were used to design the 1987 study. The 1987 study also investigated the effects of gas cooking appliances which were not considered in the 1984 study.

1987 STUDY DESIGN

The second study was conducted in 1987 and was titled "Field Evaluation

1984 Study

Type of Cooking Appliances	Type of Furnace: Electric	Type of Furnace: Gas
Electric	Home G (0,0 Cigarettes(a)) Home H (0,0 Cigarettes)	Home F (0,13 Cigarettes) (WB) Home F (Replicate, 8,4 (WB) Cigarettes)
Gas		Home A (0,0 Cigarettes) Home B (0,0 Cigarettes) (WB) Home C (0,0 Cigarettes) (WB) Home C (Replicate, 0,0 (WB) Cigarettes) Home D (18,13 Cigarettes)(WB) Home I (0,0 Cigarettes)

(a) The first number is the number of cigarettes smoked during the 7:00 AM - 3:00 PM sampling period in the kitchen. The second number is the number of cigarettes smoked during the 3:00 PM - 11:00 PM sampling period in the living room.

(WB) Woodburning fireplace in use during study.

Figure 4-1. Overview of Data from the Pilot Study of Sampling and Analysis for Polynuclear Aromatic Compounds in Indoor Air Which Were Used in this Comparison Study

of Sampling and Analysis for Organic Pollutants in Indoor Air". The objectives of the 1987 study were:

1. To field test a newly developed prototype indoor air sampler
2. To characterize the concentrations of PAH nitrogen heterocyclic compounds and nitro-PAH compounds in indoor air
3. To assess contributions of various indoor combustion sources to indoor PAH concentration levels.

This study used a new prototype indoor air sampler developed by EPA's Environmental Monitoring Systems Laboratory (3). This new sampler allows the pumping unit to be placed inside the home with the air sampling unit. The sampler is designed to be quiet, transportable, and unobtrusive, with no requirement to vent the sampler exhaust outside. For the 1987 study, the sampler was equipped with a quartz fiber filter to collect particulate matter and XAD-4 resin to trap vapors.

Since the results of the 1984 study found that woodburning fireplaces were not significant contributors to PAH levels and that the bedroom sampling period had relatively low levels of PAH, these two factors were eliminated from the design of the 1987 study. The 1987 study investigated the contributions of (1) gas heating systems, (2) gas cooking appliances, and (3) cigarette smoking to the indoor concentration levels of PAH and related compounds.

At each sample home, 8-hour samples were taken at each of two indoor locations within the home: kitchen (7:00 AM to 3:00 PM) and living room (3:00 PM to 11:00 PM). A 16-hour ambient air sample was also taken outside the home to coincide with the two 8-hour indoor samples. At each home, the air exchange rate was determined by the decay rate of SF_6 injected into the house. A questionnaire was completed by the residents of each sample home to record the number of cigarettes smoked and various other activities during sampling that might have affected concentrations of indoor PAH compound levels. The sample design used for the 1987 study is given in Figure 4-2. Note that two of the homes (Homes 3 and 8) were sampled twice. This provided for an estimate to be made of the day-to-day variability of concentration levels within the same homes.

1987 Study

Type of Cooking Appliances	Type of Furnace: Electric	Type of Furnace: Gas
Electric	Home 7 (0,0 Cigarettes(a)) Home 3 (6,9 Cigarettes) Home 3 (Replicate, 4,0 Cigarettes)	Home 1 (0,0 Cigarettes) Home 6 (9,12 Cigarettes) Home 5 (11,20 Cigarettes)
Gas		Home 8 (0,0 Cigarettes) Home 8 (Replicate, 0,0 Cigarettes) Home 2 (10,16 Cigarettes) Home 4 (7,15 Cigarettes)

(a) The first number is the number of cigarettes smoked during the 7:00 AM - 3:00 PM sampling period in the kitchen. The second number is the number of cigarettes smoked during the 3:00 PM - 11:00 PM sampling period in the living room.

Figure 4-2. Sampling Design for Field Evaluation of Sampling and Analysis For Organic Pollutants in Indoor Air

Results of the 1987 study found that the type of heating system and cigarette smoking had the greatest effects on the indoor levels of most PAH and nitro-PAH compounds. And, although not statistically significant for most compounds, homes with electric cooking appliances rather than gas cooking appliances had higher levels of most target compounds. This is contrary to what one would expect. This is one of the key findings to be investigated in this comparison study.

ANALYSIS DATA SET

To compare 1984 results against the 1987 results we constructed an analysis data set that contained the combined data from both studies. Because the 1984 study did not investigate all the same factors and compounds as the 1987 study, the two existing data sets could not simply be merged. Rather, additional information from the questionnaires completed for each of the 1984 study homes had to be extracted, and the data put into a format compatible with the 1987 study. The following types of manipulations were performed to create a data set appropriate for analysis.

- TYPE OF COOKING APPLIANCE and NUMBER OF CIGARETTES SMOKED were not used as design factors in the 1984 study but this information was available from the questionnaire data. Also, as indicated earlier, a separate breakdown on the number of cigarettes smoked during each sampling period was not available for two of the sample homes. Thus, these two homes were omitted from the analysis.

- The bedroom measurements from the 1984 study were omitted because the 1987 study did not consider this sampling location.

- Only those compounds that were common to both studies were included in the analysis.

- The compounds 1-nitropyrene and 2-nitrofluoranthene were excluded from this study. In the 1984 study, only one 24-hour sample per home was analyzed for each of these two compounds. Thus, the number of available data points was considered too few to make valid comparisons of modeling results between the two studies.

A listing of the combined analysis data set is given in Table A.1 of Appendix A. Each record in this data set corresponds to a single sampling period. The data contains identification information concerning the home sampled, characteristics of the home, the date and time of sampling, and the measured concentration levels for each of the compounds common to both studies.

SECTION 5

RESULTS AND DISCUSSION

COMPARISON OF CONCENTRATION RANGES

Table 5-1 presents a comparison of the concentration ranges observed between the 1984 and 1987 studies. Each range represents the minimum and maximum concentration measurements observed over the combined kitchen and living room sampling locations. Note that except for quinoline and isoquinoline, there is good agreement between the concentration ranges. The discrepancies in ranges for quinoline and isoquinoline are due to breakthrough of the PUF traps used in the 1984 study. The 1987 study used XAD-4 traps which did not experience the same level of breakthrough.

The comparison of ranges for anthracene does not include one outlier value of 72.63 ng/m^3 obtained during the 1984 study. This high value resulted from placing the sampler immediately over the stove while bacon and eggs were being cooked. This was the only time that the sampler was placed directly over the stove. Therefore we felt that this value was not comparable to the other measurements taken.

We had originally also planned to compare the two studies with respect to the mean concentration levels for each combination of the factors sampling location, type of heating system, and type of cooking appliance. However, differences in the number of cigarettes smoked during the sampling periods does not allow for meaningful comparisons to be made. Appropriate comparisons can be made only from the modeling results where adjustments can be made to eliminate the effects of cigarette smoking. These results are presented in the next section.

TABLE 5-1. A COMPARISON OF THE INDOOR(a) CONCENTRATIONS BETWEEN THE 1984 AND 1987 STUDIES

Compound	Concentration Levels (b)			
	1984 STUDY		1987 STUDY	
	Minimum Value	Maximum Value	Minimum Value	Maxiumum Value
Quinoline	0.29	31.23	8.50	1100.00
Isoquinoline	0.52	15.50	8.10	620.00
Phenanthrene	33.77	143.58	55.00	210.00
Anthracene	1.48	13.25(c)	0.76	15.00
Fluoranthene	9.23	37.37	5.10	23.00
Pyrene	4.30	18.10	3.30	17.00
Cyclopenta(c,d)pyrene	0.00	1.72	0.12	2.00
Benz(a)anthracene	0.26	2.77	0.17	3.40
Chrysene	0.57	5.25	0.48	7.20
Benzofluoranthenes	0.18	5.83	0.51	5.10
Benzo(e)pyrene	0.00	3.12	0.33	10.00
Benzo(a)pyrene	0.00	3.33	0.25	3.30
Indeno(1,2,3-c,d)pyrene	0.00	2.60	0.18	1.80
Benzo(g,h,i)perylene	0.00	3.15	0.32	2.50
Coronene	0.00	3.08	0.17	1.40
Total Extractable Organic Mass(d)	0.03	0.30	0.06	0.57

(a) Indoor refers to samples taken in the kitchen and living room.
(b) Concentrations are in ng/m^3.
(c) An anthracene value of 72.63 ng/m^3 for House=I, Location=Kitchen was omitted.
(d) Concentrations for total extractable organic mass are in mg/m^3.

Comparison of 1984 and 1987 Modeling Results

In the 1987 study a statistical model was used to estimate the effects of different indoor combustion sources on the concentration levels of each compound. To evaluate and validate these results, the 1984 data were fit to the same model used in the 1987 study. The model is given by

$$C = \mu + HS + ST + L + \beta_1 \cdot CIG + \beta_2 \cdot AER + H + D + E, \qquad (1)$$

where

C = the measured concentration for the target compound
μ = overall average PAH concentration
HS = effect due to the type of heating system
ST = effect due to the type of cooking appliances (stove)
L = the effect due to the sampling location within the home
$\beta_1 \cdot CIG$ = the effect of cigarette smoking on PAH levels
$\beta_2 \cdot AER$ = the effect of air exchange rate (exchanges/hour) on PAH levels
H = effect of sampling a specific home (i.e. variability in PAH levels due to home-to-home differences)
D = the effect of sampling on a specific day (i.e. variability due to day-to-day differences in PAH levels), and
E = random error due to the combined effects of any other factors not included in the model.

The estimated model parameters obtained using the 1984 data were then compared against the parameter estimates previously obtained using the 1987 study data. The effects of type of heating system, type of cooking appliances, number of cigarettes smoked, and sampling location were quantified by estimating the following values:

1. THE TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN HOMES HAVING GAS VERSUS ELECTRIC HEATING SYSTEMS

2. THE TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN HOMES HAVING GAS VERSUS ELECTRIC COOKING APPLIANCES

3. THE TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN HOMES IN WHICH 10 CIGARETTES ARE SMOKED IN AN 8-HOUR PERIOD VERSUS NO CIGARETTES

4. THE TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN THE LIVING ROOM AND KITCHEN SAMPLING LOCATIONS.

Figures B.1 through B.16 in Appendix B present graphs of these estimated differences and 95 percent confidence intervals for the true differences in average levels for the 16 compounds investigated. The estimated differences and confidence intervals from the two studies are given side-by-side. Each asterisk represents the estimated difference and the vertical bar represents a 95 percent confidence interval for the true difference in average levels. The actual value for each estimated difference and each lower (LCL) and upper (UCL) 95 percent confidence limit on the difference are given in Table B.1 in Appendix B.

On the graphs in Appendix B, the vertical bars for HEATING SYSTEM and COOKING SYSTEM estimate the differences in average concentration levels between homes having gas and electric systems. For example, a positive difference for the heating system indicates that gas heated homes are estimated to have higher average PAH levels than electrically heated homes. A negative difference indicates that electric homes are estimated to have higher levels. Similarly, a positive difference for the cooking system indicates that homes with gas cooking appliances are estimated to have higher average levels than homes with electric appliances.

For cigarette smoking we compared the effect of smoking 10 cigarettes in an 8-hour period versus no cigarettes. For those sample homes in which there were smokers present, 10 cigarettes was a typical number smoked during

an 8-hour period. Therefore we felt that comparing 10 cigarettes versus no cigarettes was the most meaningful comparison.

For sampling location we compared average levels observed in the living room against the levels observed in the kitchen. A positive difference indicates that the average concentration level is estimated to be higher in the living room than the kitchen. Although we defined the parameter as sampling location, it may be that differences in PAH levels are due more to sampling period. The kitchen samples were taken from 7:00 AM to 3:00 PM, while the living room samples were taken from 3:00 PM to 11:00 PM. Differences in cooking and other type activities during these two time periods may account more for the differences than the location within the home. The observed air exchange rates (0.20 to 0.74 exchanges per hour in the 1984 study and 0.20 to 2.00 exchanges per hour in the 1987 study) are sufficiently high to create a thorough mixing of the air throughout the home, thereby minimizing any expected differences in air concentration levels due to sampling location.

Note from the graphs in Appendix B that, except for the compounds quinoline and isoquinoline, the vast majority of the pairs of confidence intervals overlap, indicating there is no statistical evidence that the estimated effects of gas heating system, gas cooking appliances, cigarette smoking, and sampling location differ between the two studies. This suggests there is a good degree of consistency in the modeling results between the two studies.

For quinoline and isoquinoline, the results for the 1984 study indicate that cigarette smoking and type of heating system have much smaller effects than indicated by the 1987 study. Recall that much lower quinoline and isoquinoline measurements were obtained for the 1984 study due to breakthrough in the PUF traps used in this study. The 1987 study used XAD-4 traps which did not experience the same degree of breakthrough. The differences between the two studies for quinoline and isoquinoline are best seen by the comparisons for cigarette smoking. The confidence intervals do not overlap at all, indicating an inconsistency in results due to the two different types of vapor traps used.

Initially, we also found an inconsistency in 1984 and 1987 study results for anthracene. The initial results for anthracene indicated much

larger confidence intervals for the 1984 estimates. However, this was due to the outlier value of 72.63 ng/m^3 we discussed earlier. Removing this value resulted in much more consistent results between the two studies as indicted in Figure B.4.

In the 1987 study, higher levels of several compounds were found in homes having electric cooking appliances rather than gas appliances. This is contrary to what one would expect and contrary to the findings in 1984. For the 1984 study, the estimated coefficients in Table B.1 for the type of cooking appliance are positive for most compounds which indicate that gas appliance homes had higher average levels for most of the target compounds. Electric appliances were associated with higher levels only for the compounds phenanthrene, fluoranthene, pyrene, and coronene. Further, the type of cooking appliance did not have a statistically significant effect on the levels of any of the compounds except benzo(e)pyrene. The lack of statistical significance is demonstrated by the fact that zero is included in each confidence interval as a possible value for the true average difference in concentration levels between gas and electric appliance homes. This is still an open question. Results from upcoming studies will provide additional evidence to determine the true effect, if any, of gas versus electric cooking appliances.

Estimated PAH Contributions of Indoor Combustion Sources Based on Combined 1984 and 1987 Study Data

Except for quinoline and isoquinoline, there is no statistical evidence that the modeling results are different between the 1984 and 1987 studies. Therefore, the data for the two studies were combined into one data set and used to fit the model given in Equation (1). Using the combined study data to fit the model provides more precise estimates of the true contributions of the various different combustion sources on indoor PAH levels.

The modeling results are presented in Figures 5-1 through 5-14 for all the compounds except quinoline and isoquinoline, which were not included because the 1984 and 1987 results were inconsistent for these two compounds.

Each asterisk and vertical bar on the graph for a given compound represents a point estimate and 95 percent confidence interval,

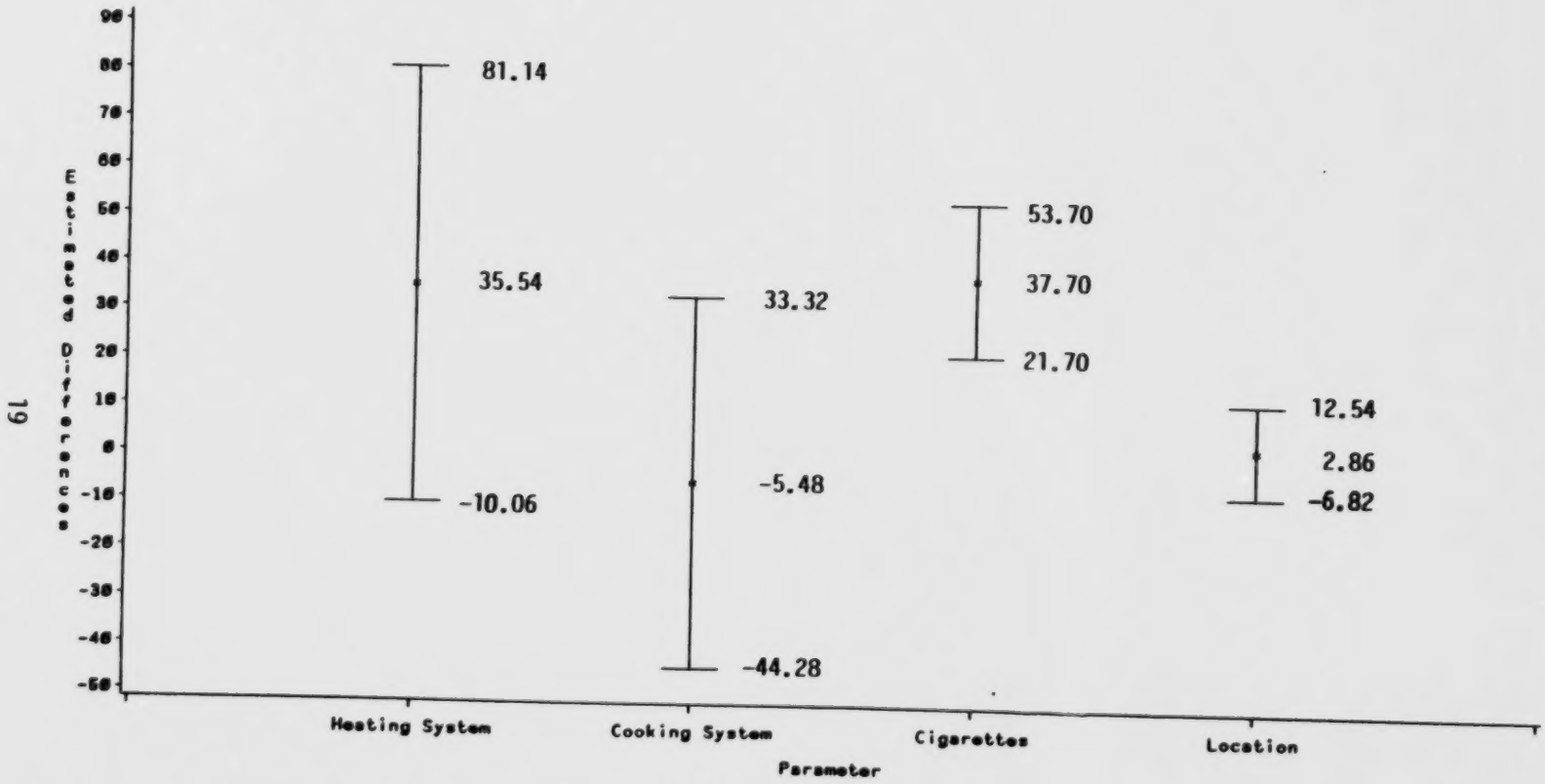

Figure 5-1. Estimated Differences (and 95% Confidence Intervals) in Average Phenanthrene Levels Due to Each Experimental Factor--Combined 1984 and 1987 Data (ng/m3).

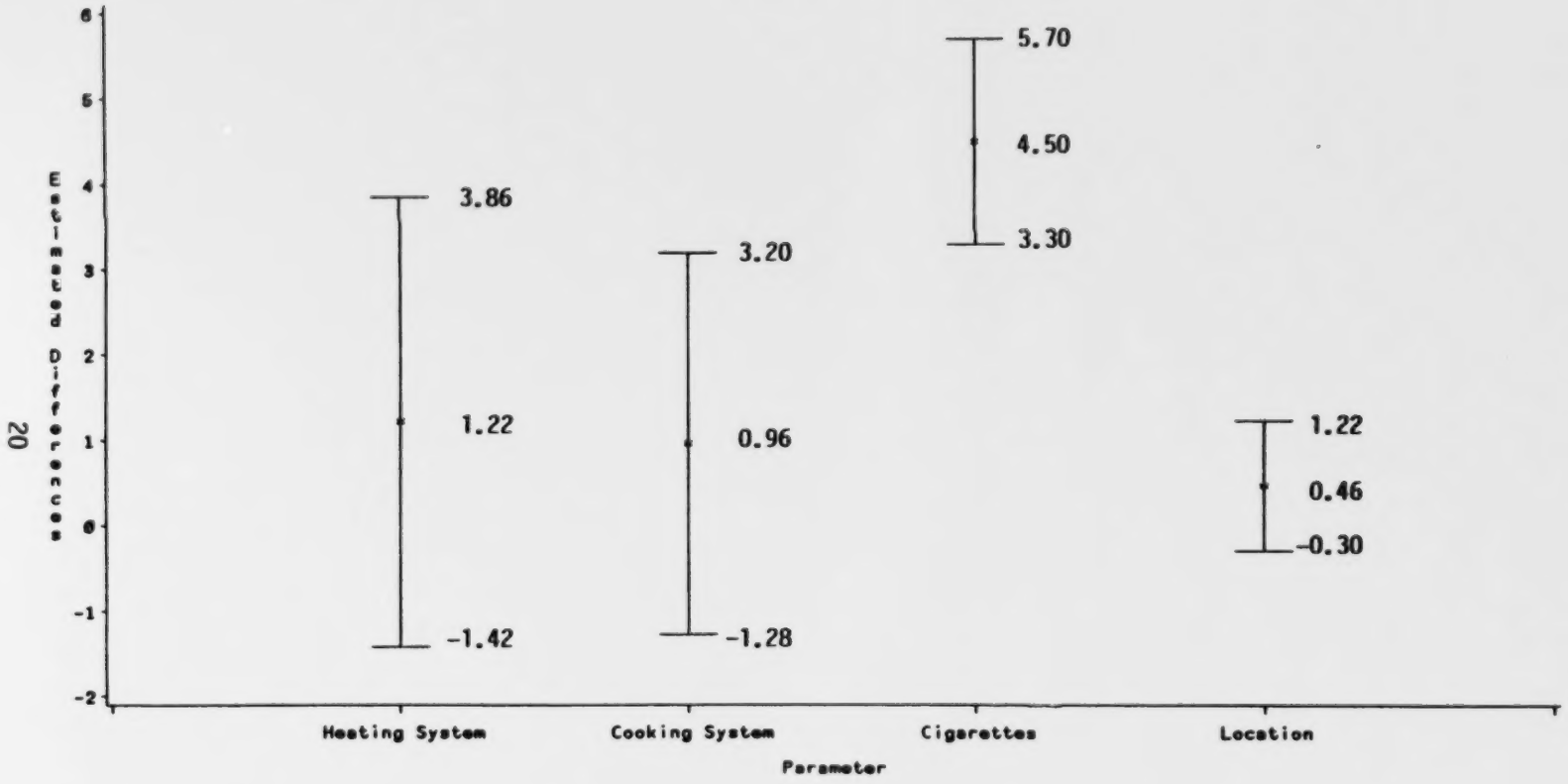

Figure 5-2. Estimated Differences (and 95% Confidence Intervals) in Average Anthracene Levels Due to Each Experimental Factor--Combined 1984 and 1987 Data (ng/m3).

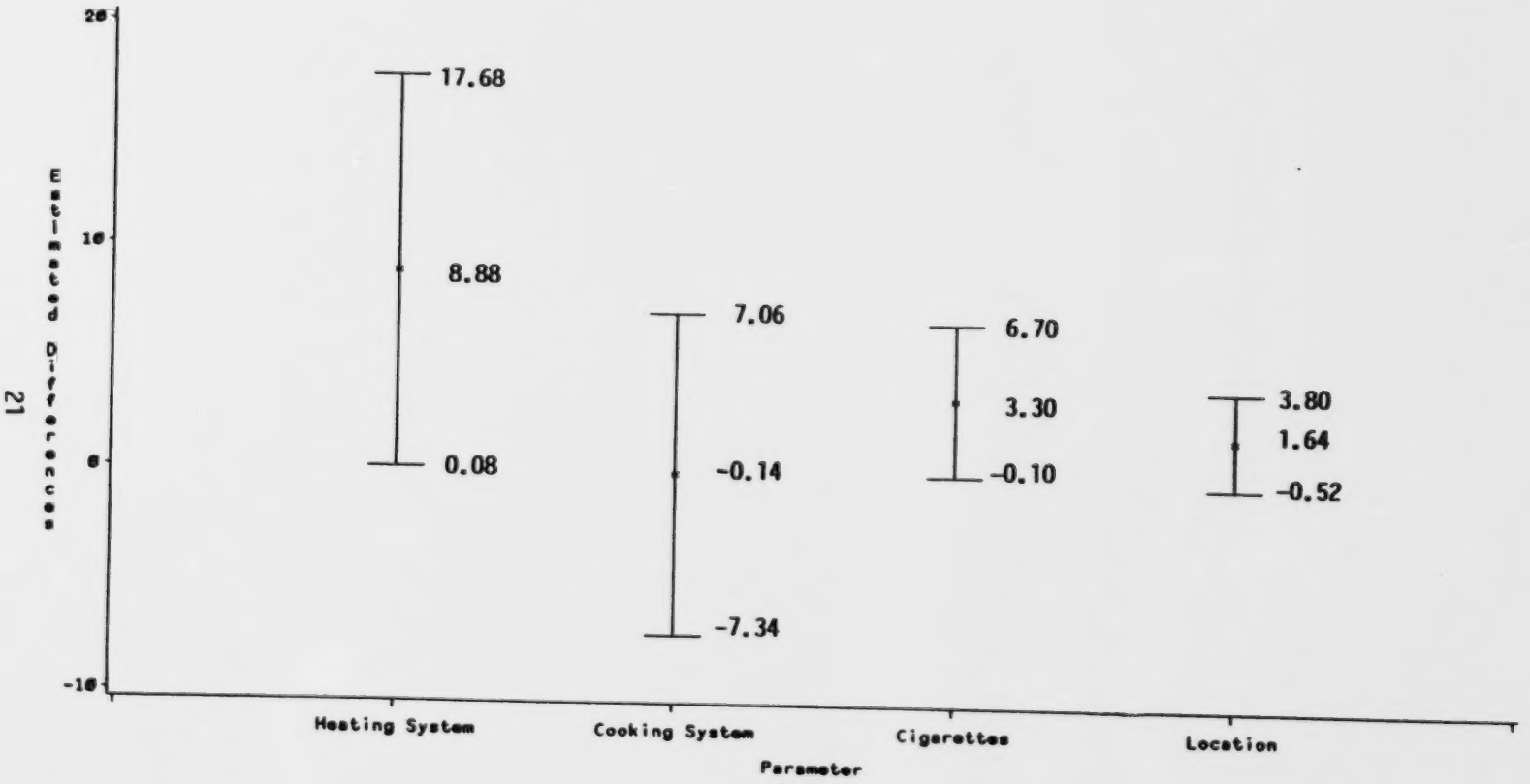

Figure 5-3. Estimated Differences (and 95% Confidence Intervals) in Average Fluoranthene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m3).

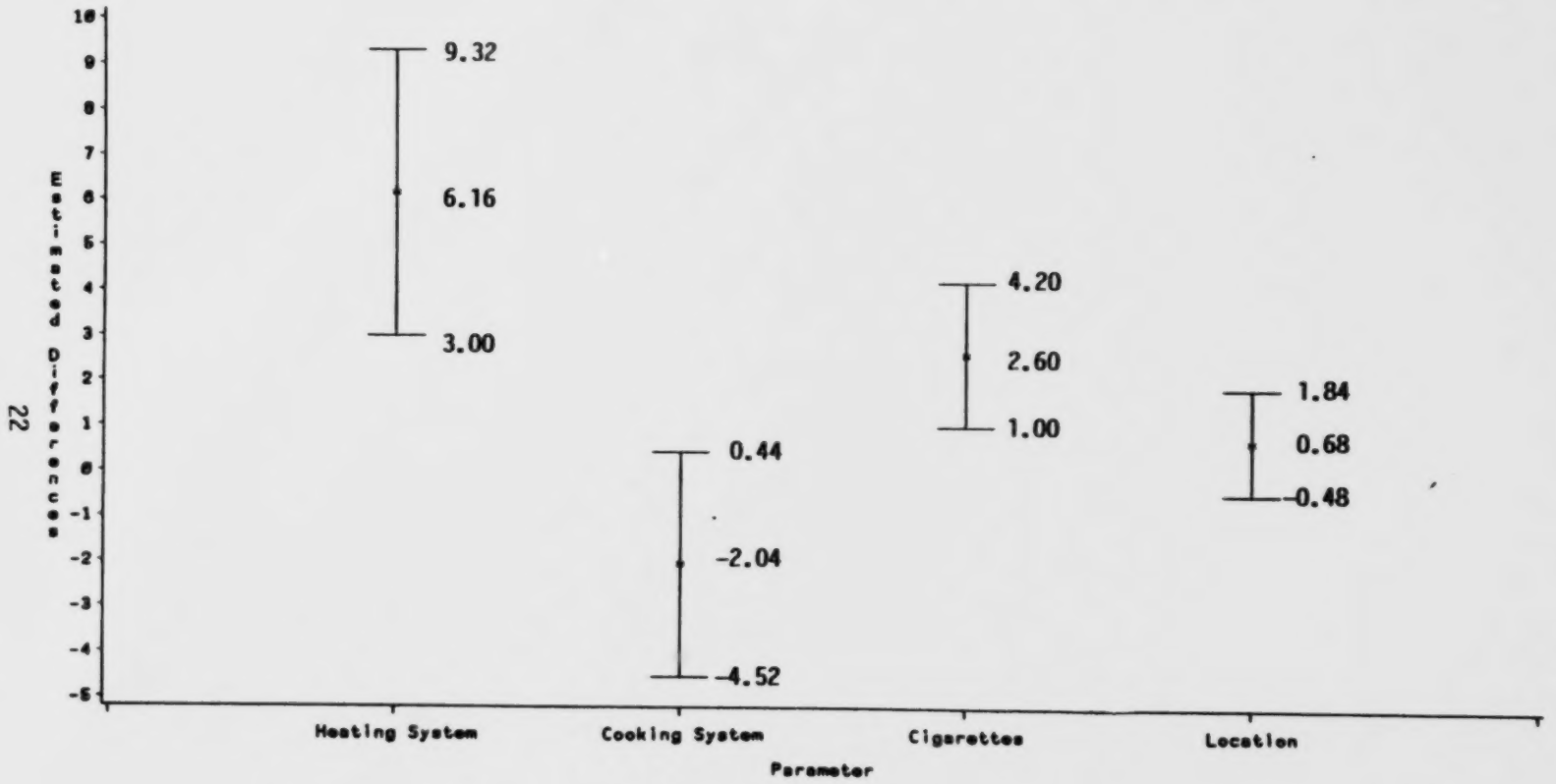

Figure 5-4. Estimated Differences (and 95% Confidence Intervals) in Average Pyrene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m3).

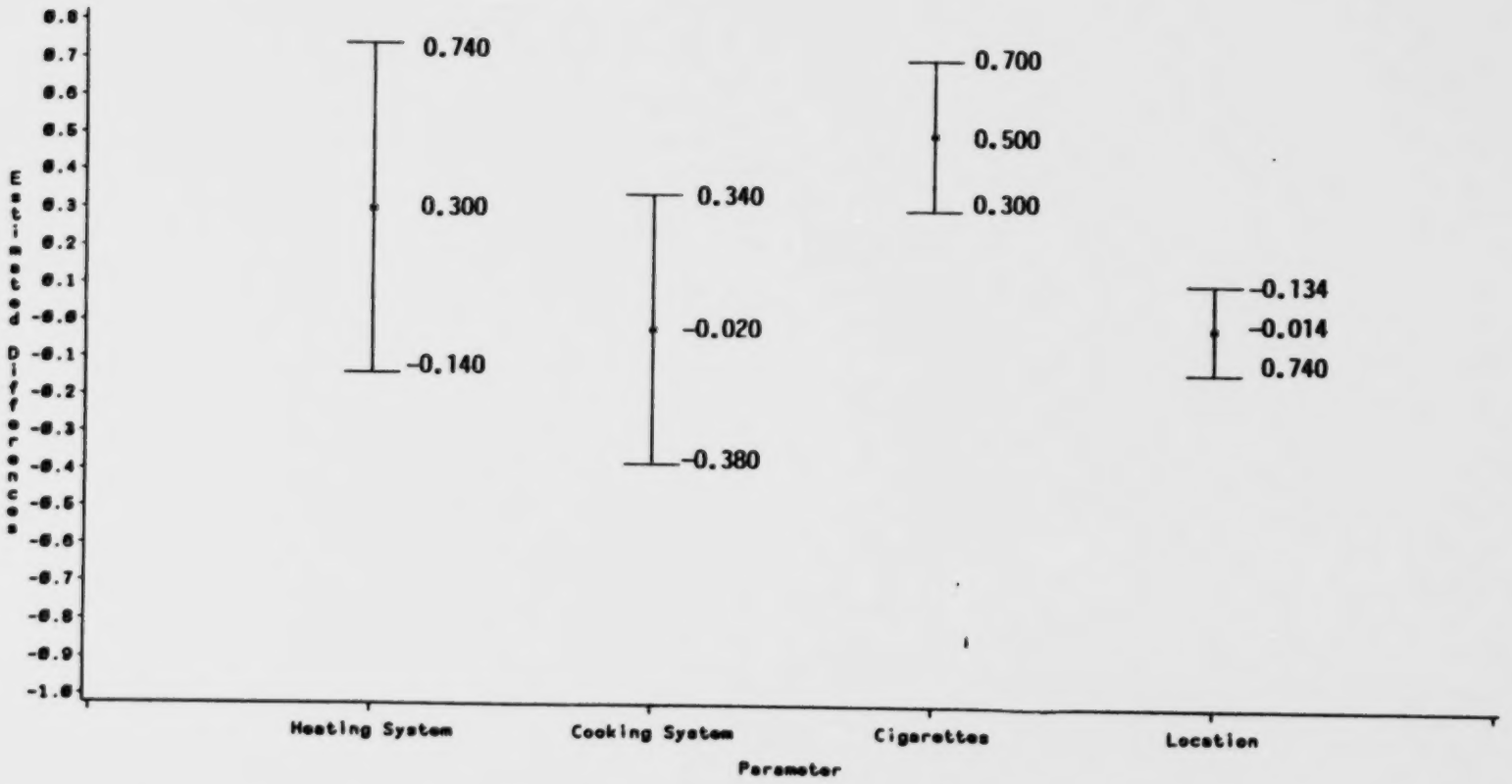

Figure 5-5. Estimated Differences (and 95% Confidence Intervals) in Average Cyclopenta(c,d)pyrene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m^3).

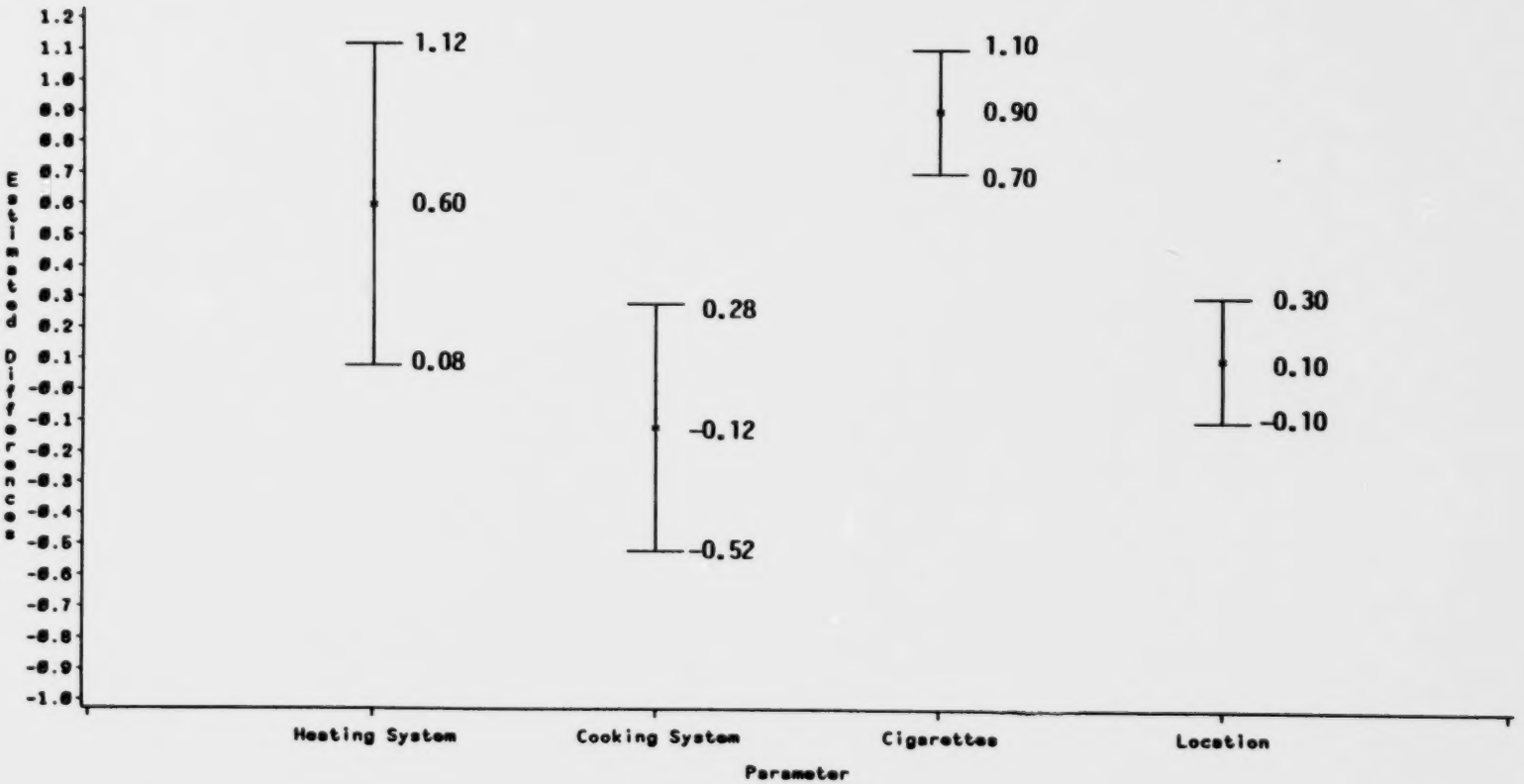

Figure 5-6. Estimated Differences (and 95% Confidence Intervals) in Average Benz(a)anthracene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m^3).

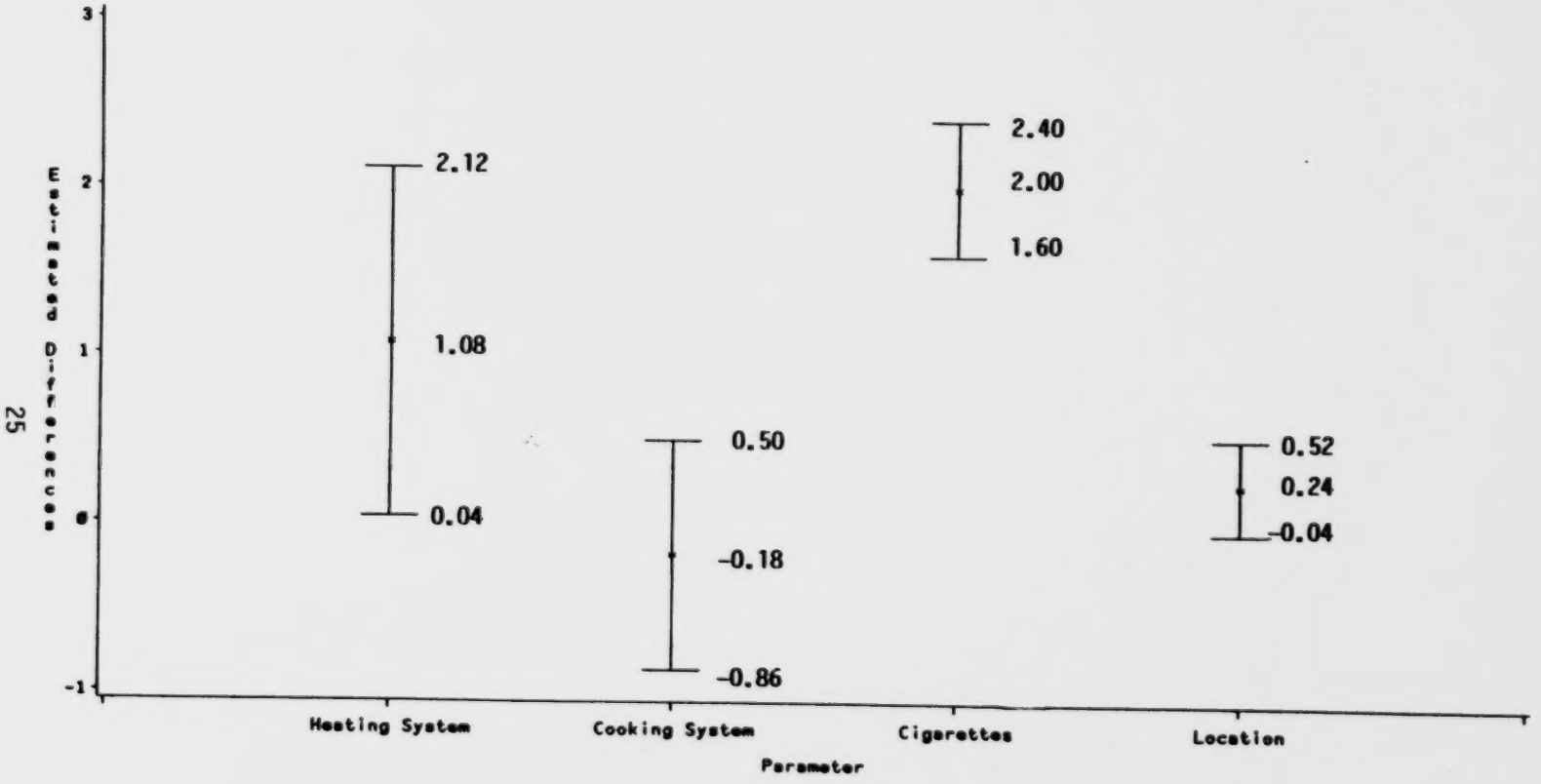

Figure 5-7. Estimated Differences (and 95% Confidence Intervals) in Average Chrysene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m3).

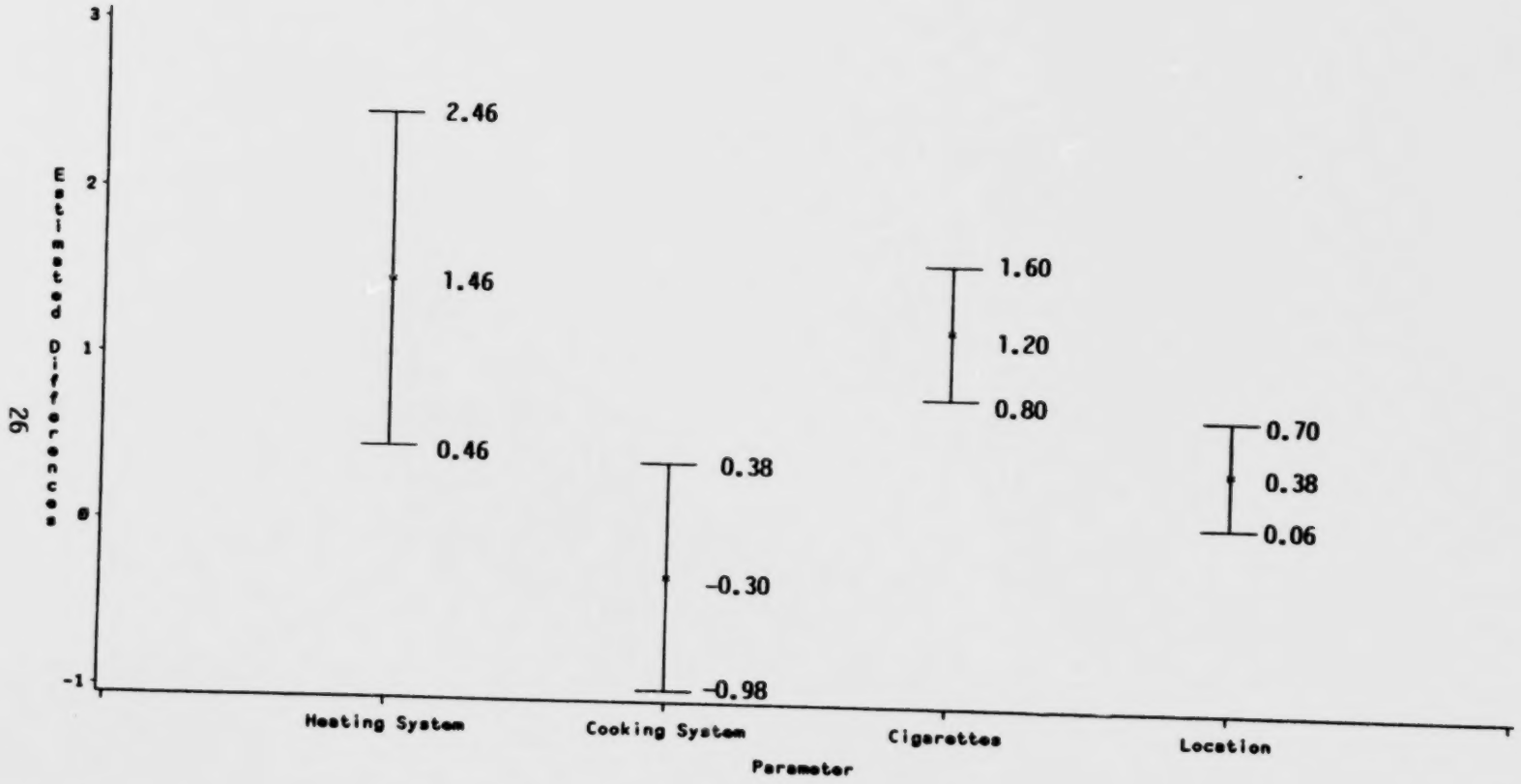

Figure 5-8. Estimated Differences (and 95% Confidence Intervals) in Average Benzofluoranthene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m3).

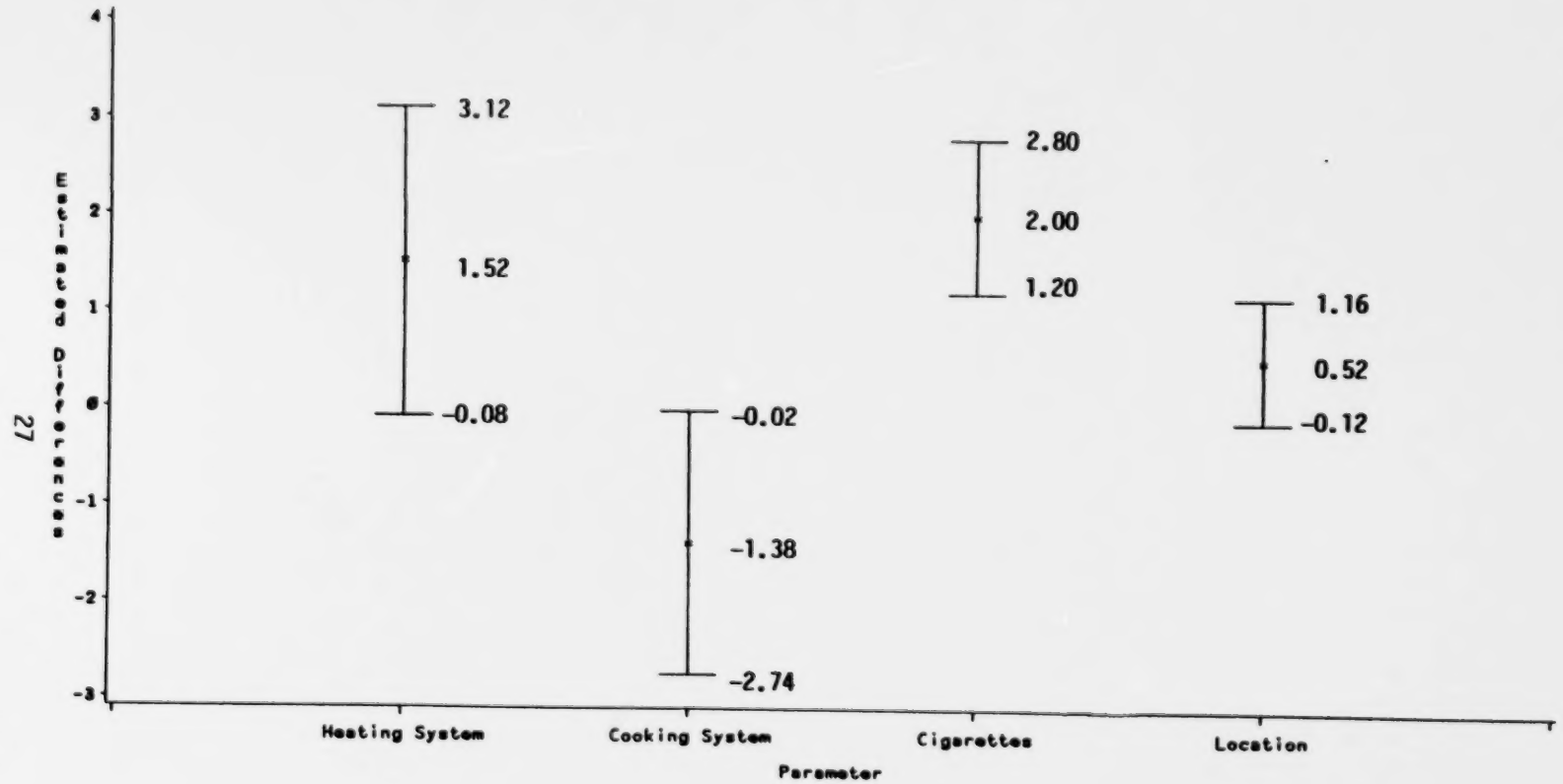

Figure 5-9. Estimated Differences (and 95% Confidence Intervals) in Average Benzo(e)pyrene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m^3).

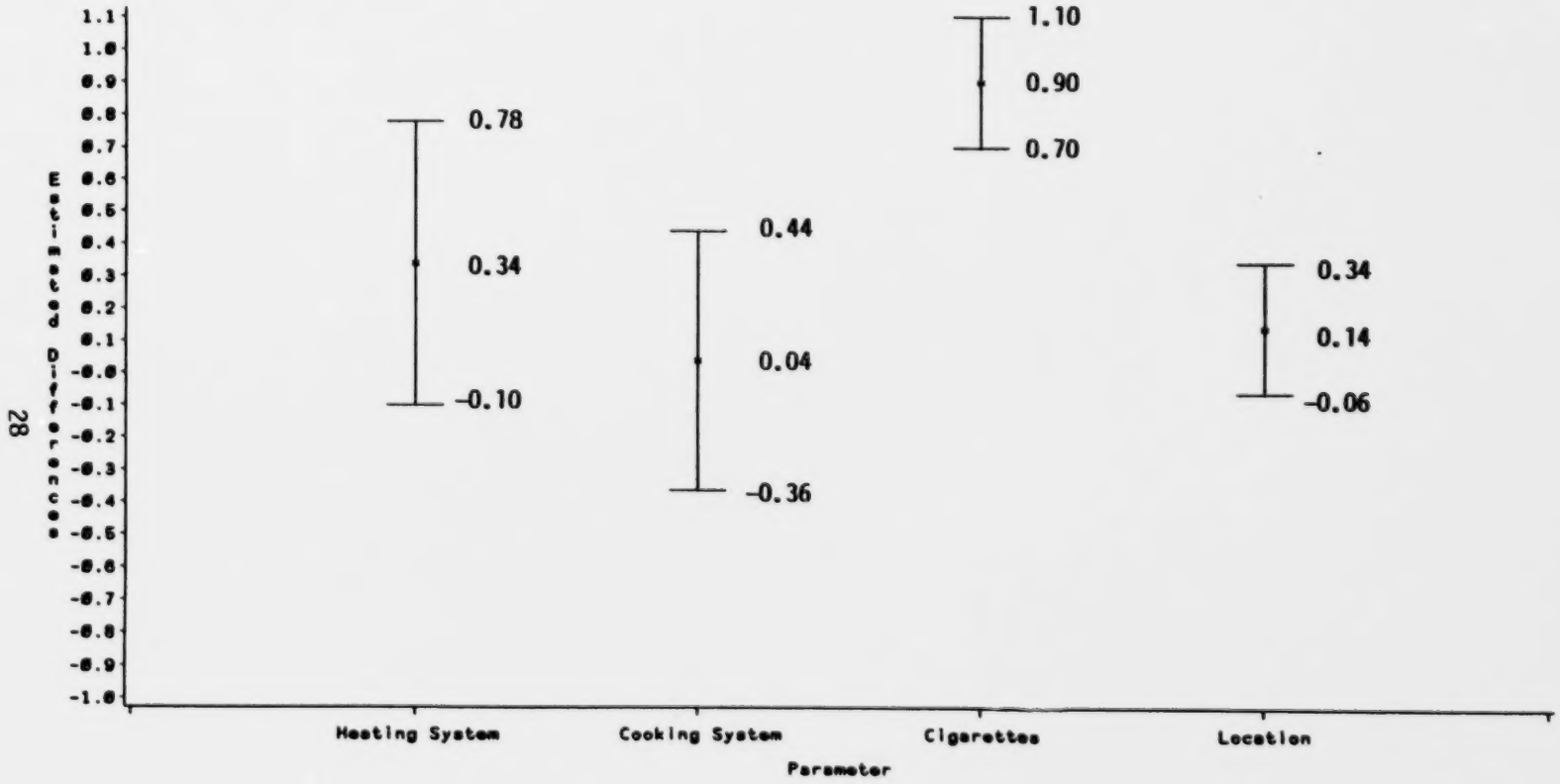

Figure 5-10. Estimated Differences (and 95% Confidence Intervals) in Average Benzo(a)pyrene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m3).

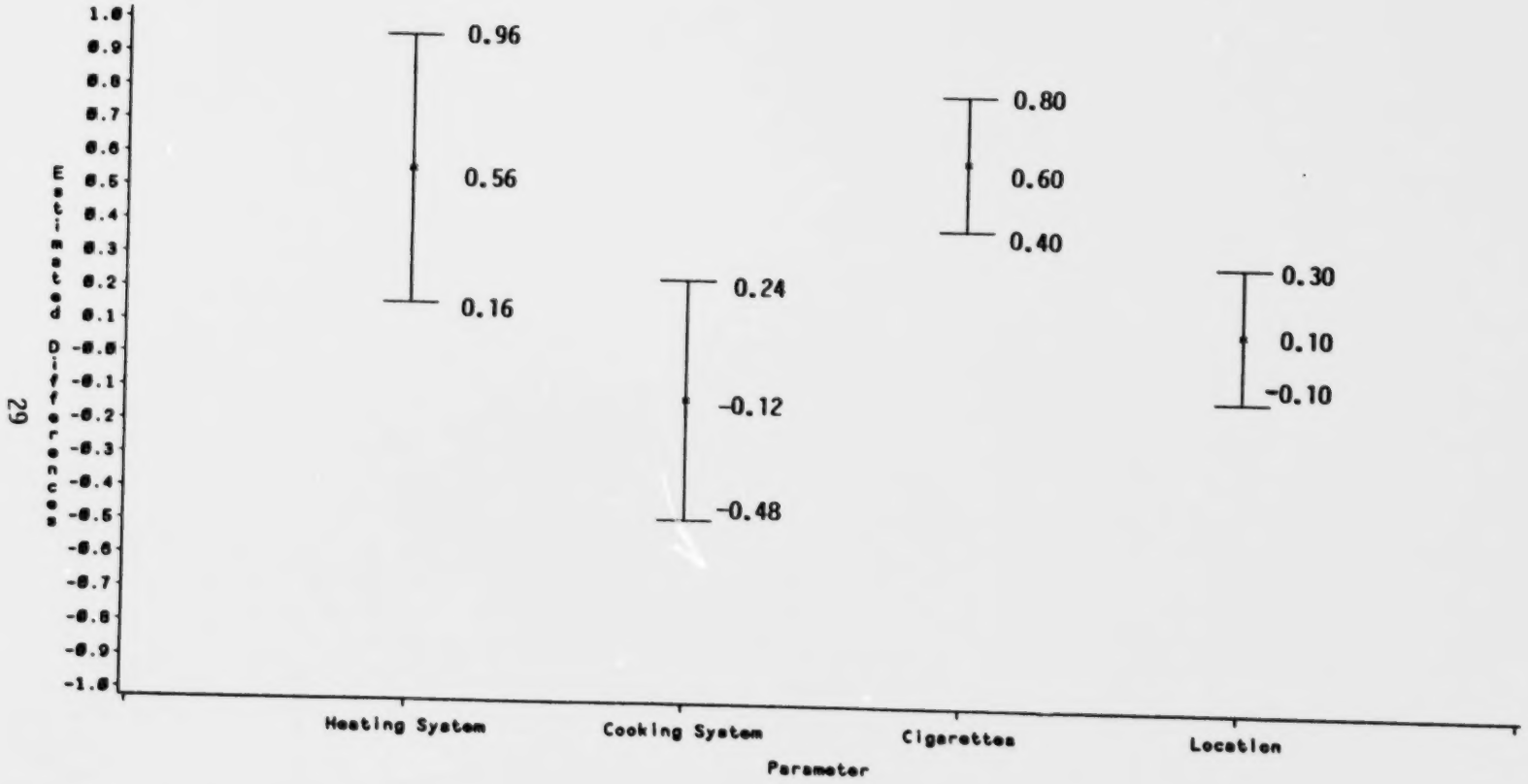

Figure 5-11. Estimated Differences (and 95% Confidence Intervals) in Average Indeno(1,2,3-c,d)pyrene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m3).

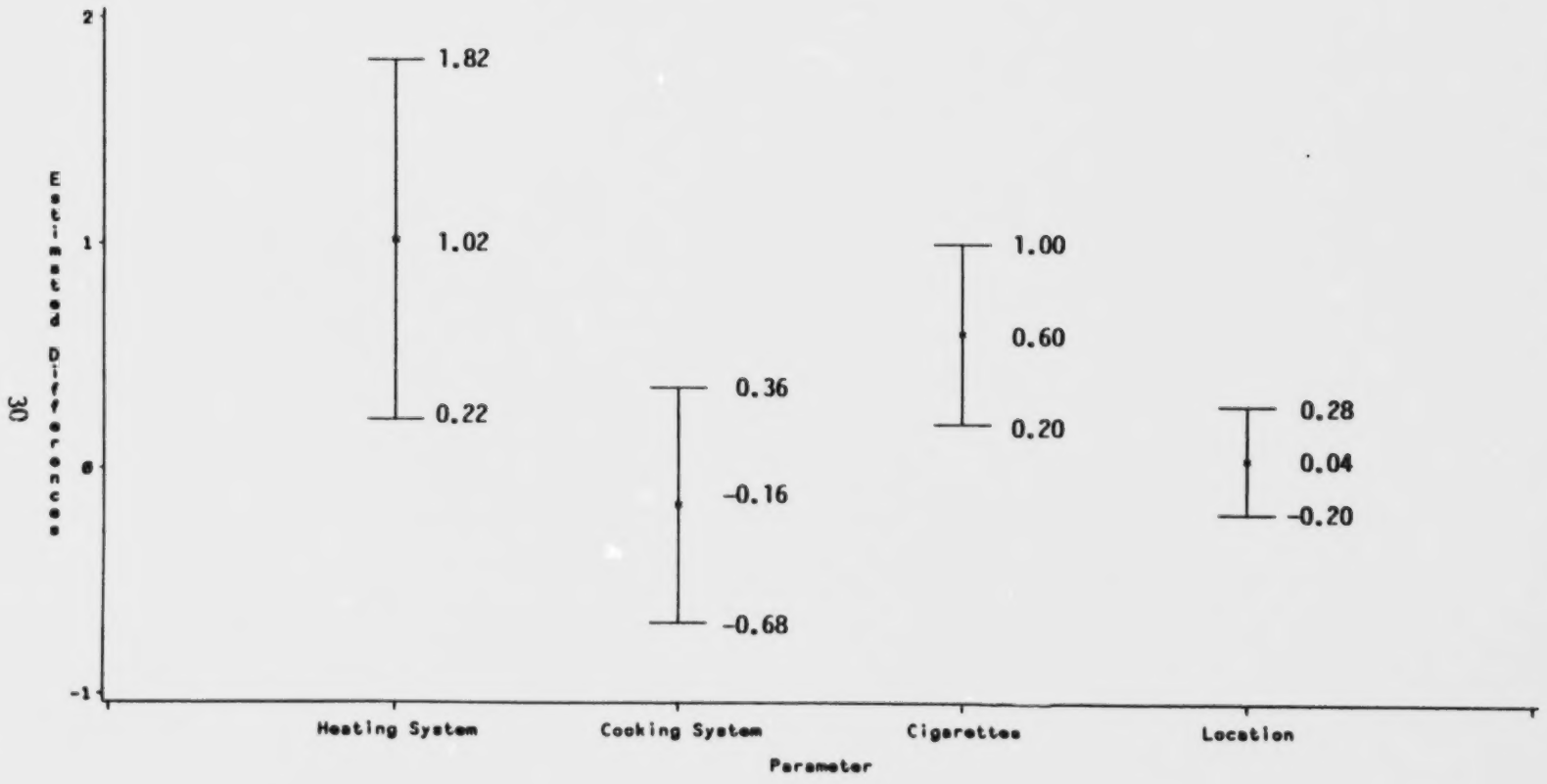

Figure 5-12. Estimated Differences (and 95% Confidence Intervals) in Average Benzo(g,h,i)perylene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m^3).

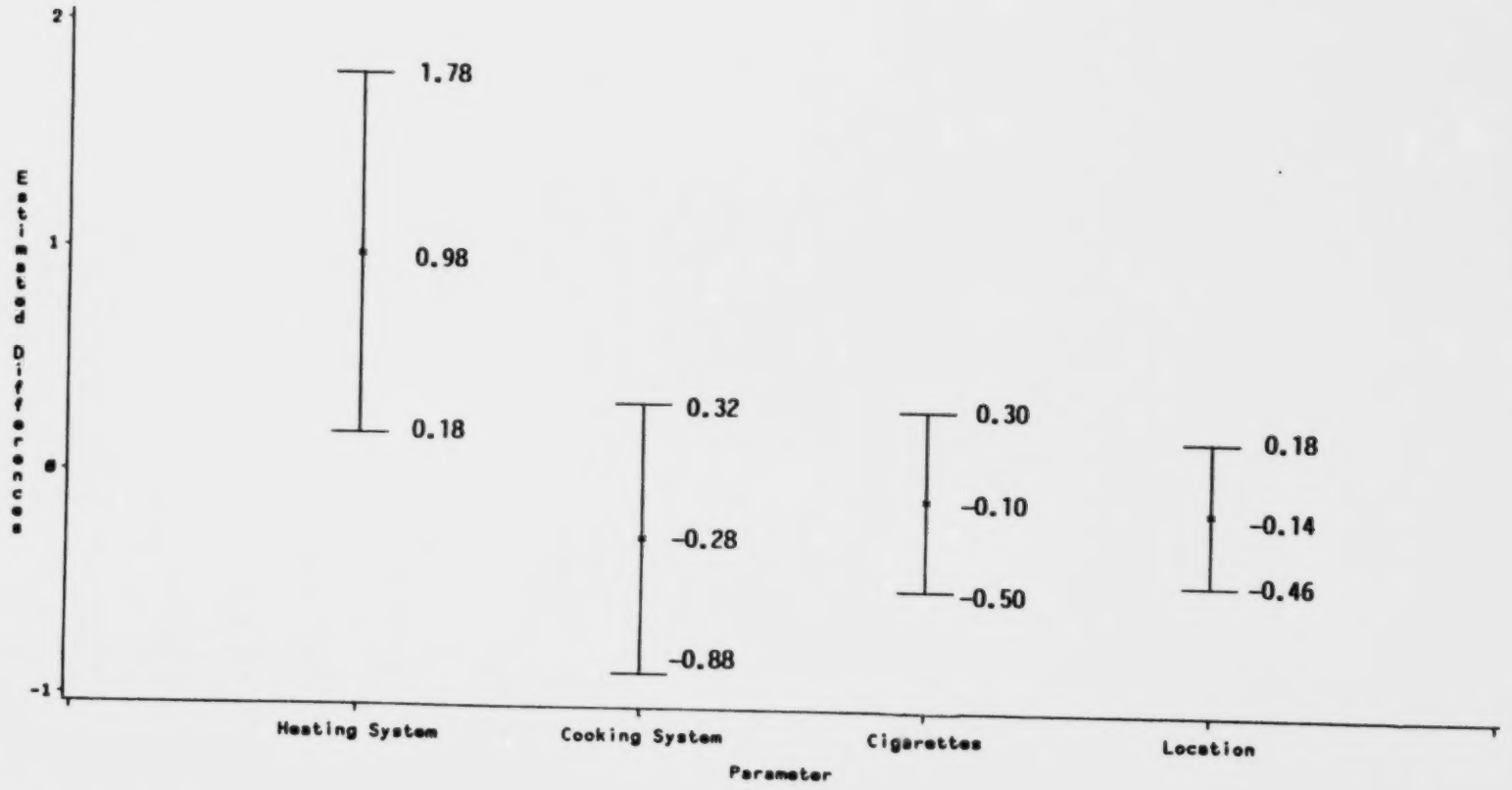

Figure 5-13. Estimated Differences (and 95% Confidence Intervals) in Average Coronene Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (ng/m^3).

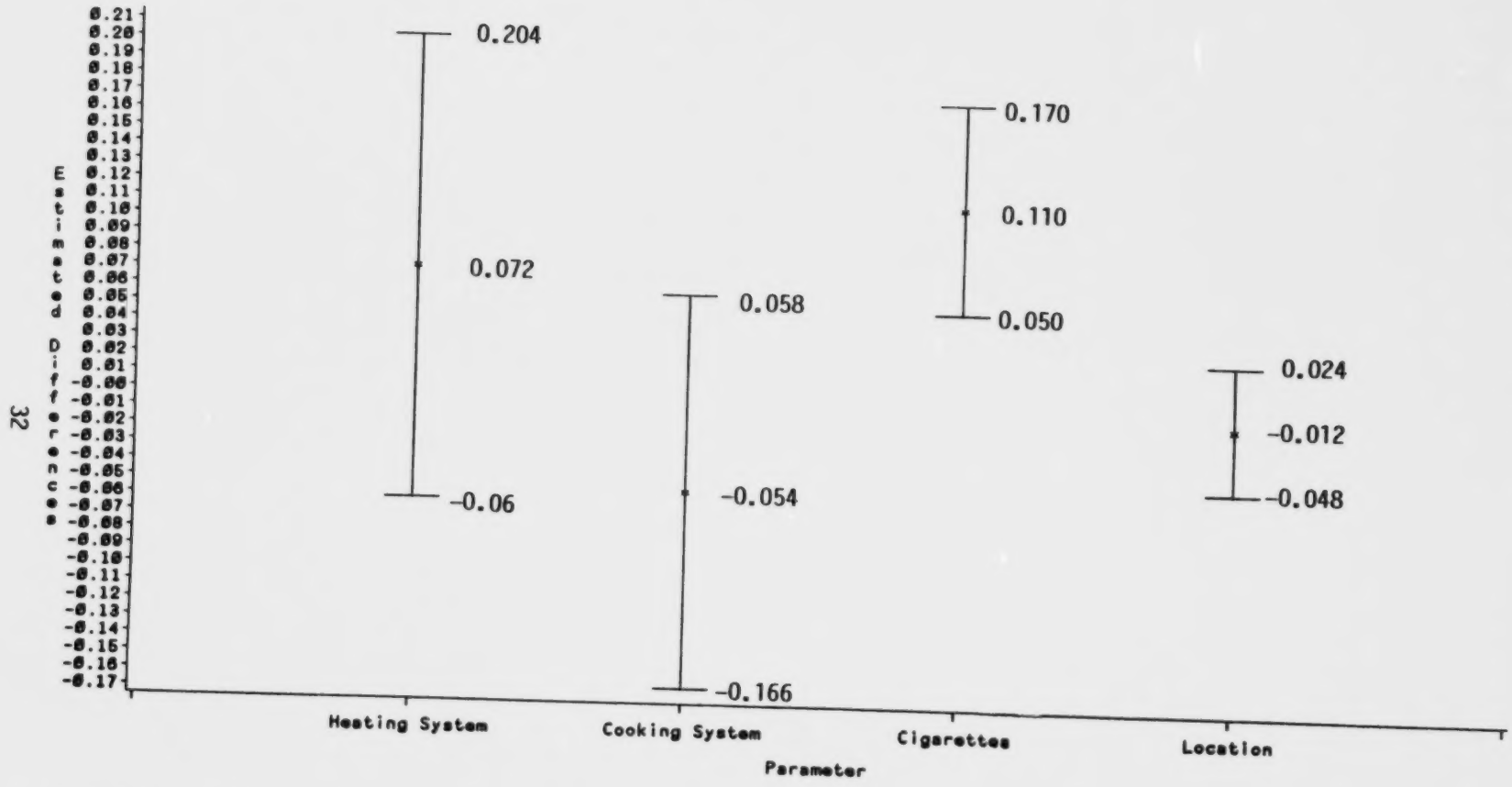

Figure 5-14. Estimated Differences (and 95% Confidence Intervals) in Average Total Extractable Organic Mass Levels Due to Each Experimental Factor—Combined 1984 and 1987 Data (mg/m3).

respectively, for the true difference in average concentration levels due to the effect of the corresponding experimental factor. The actual values of the point estimates and lower and upper 95 percent confidence limits are given beside the vertical bars. The four vertical bars represent:

1. THE ESTIMATED TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN HOMES HAVING GAS VERSUS ELECTRIC HEATING SYSTEMS

2. THE ESTIMATED TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN HOMES HAVING GAS VERSUS ELECTRIC COOKING APPLIANCES

3. THE ESTIMATED TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN HOMES IN WHICH 10 CIGARETTES ARE SMOKED DURING AN 8-HOUR PERIOD VERSUS HOMES IN WHICH THERE IS NO SMOKING

4. THE ESTIMATED TRUE DIFFERENCE IN AVERAGE CONCENTRATION LEVELS BETWEEN THE LIVING ROOM AND KITCHEN SAMPLING LOCATIONS.

A positive value for these estimates indicates an increase in concentration as a result of gas heating, gas cooking, smoking, or living room sampling. As indicated by the heights of the vertical bars, the figures show that gas heating systems and cigarette smoking produce the largest increases in the levels of indoor PAH concentration levels.

The type of cooking appliances has the least effect on the indoor PAH levels. The estimated effect of the type of cooking appliances based on the combined data sets is negative for most compounds, indicating that electric cooking appliances are associated with higher average PAH levels than gas appliances. However, the effect of the type of cooking appliance is not statistically significant (at the 5 percent level) for any of the compounds except benzo(e)pyrene. This can be seen from the 95 percent confidence limits given on the graphs. The confidence intervals contain both negative and positive values, thus indicating zero is a possible value for the true difference in average levels between homes with gas versus electric appliances. For benzo(e)pyrene, the confidence interval contains only negative values, thus indicating that electric appliances are associated with higher levels than gas appliances. The upper confidence limit is near

zero, however, and therefore it is likely that this is due to random chance resulting from the large number of comparisons being made.

Although the combined 1984 and 1987 data estimate overall higher PAH levels for homes with electric rather than gas cooking appliances, the data for the individual years are contradictory. Further, both the 1984 and 1987 studies indicate there is considerable uncertainty in the available data, and thus more data are needed to better understand the true effect of gas cooking appliances.

The size of each vertical bar on the graphs indicates the uncertainty in estimating the effect of the corresponding factor. For example, the smaller bars associated with cigarette smoking and sampling location indicate that the effects of these factors are known with more certainty than the other experimental factors. Larger bars are associated with the type of heating system and type of cooking appliances, indicating there is more uncertainty in the true effects of these two factors. In an upcoming study, the actual amount of gas used will be recorded by monitoring the gas meter during sampling. This may help to better assess the true effects of gas heating and cooking appliances on indoor PAH levels.

PREDICTING PAH TARGET COMPOUND LEVELS FROM MEASURED LEVELS OF POTENTIAL MARKER COMPOUNDS

There are a number of PAH and related compounds that are found in indoor air and that are considered to be possible carcinogens. Therefore, PAH monitoring studies typically include a large number of compounds to determine which target compounds are present in significant amounts. Analysis for all these compounds is quite expensive and consequently greatly increases the cost of doing monitoring studies.

One possible approach to reducing monitoring costs is to determine whether the measured levels of certain PAH compounds can be used to predict the levels of other target compounds. If such "marker" compounds can be found, other target PAH compounds will not have to be directly measured because they can then be predicted from the measured levels of the marker compounds.

In the 1987 study, predictive models were developed to determine whether the compounds phenanthrene, pyrene, and fluoranthene could be used

as potential marker compounds. Each predictive model was developed as a linear equation which uses the measured concentration level of a potential marker compound to predict the level of a specific target compound. The form of the model is given by

$$\hat{C}_{Target} = a + b \cdot C_{Marker}, \qquad (2)$$

where

$\hat{C}_{Target}$ is the predicted concentration level of the target compound

C_{Marker} is the measured concentration level of the marker compound

a and b are coefficients which best relate the marker and target compound levels.

Each predictive model was developed from the 1987 study data by plotting the measured concentration levels of the potential marker compound along the x-axis and the corresponding measured concentration levels of the target compound along the y-axis. The predictive model was then obtained by fitting a least-squares regression line (4) through the plotted data. The slopes and intercepts for these predictive models are given in Appendix E of the final report for the 1987 study (2).

Results from the 1987 study showed that there are significant linear relationships between the marker and target compounds, thus indicating that measured levels of potential marker compounds can be used to help predict levels of other target compounds. In the 1987 study, correlation coefficients between potential marker compounds and most target compounds generally ranged from 0.30 to 0.80.

While the results from the 1987 study are encouraging, the true predictive abilities of the potential marker compounds are still uncertain. The models are based on limited data from only one pilot study. Proper validation of these models requires that independent sets of data be used to assess whether differences between studies and other factors significantly affect the relationships between marker and target compound levels. The data from the 1984 study were therefore used to assess the validity of the

models developed from the 1987 data. The results are given in the next section.

Validation of Predictor Models for PAH Target Compounds

The 1984 study data provide an opportunity to estimate between-study variability in the prediction equations. To do this, the same method used in the 1987 study was used to derive predictive models (Equation 2) based on the 1984 study data. For each target and marker compound pair, the 1984 and 1987 data and corresponding prediction equations were then plotted on the same graph. The graphs are given in Figures C.1 through C.36 in Appendix C. One graph is given for each combination of the 12 target compounds and 3 potential marker compounds. These graphs and the statistical results from the least-squares regression analyses on which the prediction models are based, provide an assessment of the degree of consistency between studies the models from the two studies.

Consistency between the 1984 and 1987 models was determined by the degree of statistical difference between the prediction equations. For each compound, the models were declared to be statistically different whenever the 95 percent confidence interval for the intercept or slope of the 1984 prediction equation did not overlap with either or both of the corresponding confidence intervals for the intercept and slope of the 1987 prediction equation. Whenever the corresponding confidence intervals for both the slopes and intercepts of the 1984 and 1987 prediction equations did overlap, then no statistical difference was declared.

Results from the comparison of models indicate that, except for a few compounds, there is no statistical evidence of systematic differences between the 1984 and 1987 prediction models. However, there was considerable within-study variability among the 1984 data and 1987 data. The within-study variability was sufficiently large so that the between-study variability was not considered to be statistically significant for most compounds.

The only significant differences found were for quinoline and isoquinoline. As seen in Figures C.1 through C.6, whenever the measured levels of the potential marker compounds are high, the prediction models for both quinoline and isoquinoline derived from the 1987 data predict much

higher levels than do the 1984 models. This is due to the breakthrough of the PUF vapor traps used in the 1984 study.

There were only a few other isolated statistical differences among the other compounds. These differences are not considered to be indicative of systematic differences between studies. Rather, due to the large number of comparisons being made we expected a few isolated differences due simply to chance.

PAH Target Compound Prediction Equations Based on Combined 1984 and 1987 Data

Since there were no significant differences between the 1984 and 1987 prediction models for any of the compounds except quinoline and isoquinoline, the data from the two studies were pooled to produce a single new prediction equation for each compound. Each new prediction equation was derived by fitting a least-squares regression line through the combined 1984 and 1987 study data. Plots of the individual measurements and the new prediction equations are given in Appendix D for each of the 12 PAH target compounds and 3 potential marker compounds. The intercepts and slopes of the resulting prediction equations and R-square values are given in Table 5-2. Note that the prediction equations for quinoline and isoquinoline are omitted from Table 5-2. This is because the PUF breakthroughs during the 1984 study make the 1984 and 1987 data noncomparable.

Each R-square value in Table 5-2 represents the percentage of variability in the PAH target compound levels that is attributable to variation in the potential marker compound levels. The R-square value is equivalent to the square of the correlation coefficient between the target and marker compound levels. An R-square value of 100 percent indicates that all the variation in the target compound levels can be predicted from the measured levels of the marker compound, and thus the marker compound is a perfect predictor. An R-square of zero percent indicates that there is no relationship between the levels of the target compound and the levels of the marker compound.

TABLE 5-2. LINEAR PREDICTION EQUATIONS AND R-SQUARE VALUES(a) FOR PREDICTING LEVELS(b) OF PAH TARGET COMPOUNDS FROM MEASURED LEVELS OF POTENTIAL PAH MARKER COMPOUNDS

	Phenanthrene			Pyrene			Fluoranthene		
	Intercept	Slope	R-Square	Intercept	Slope	R-Square	Intercept	Slope	R-Square
Anthracene	-0.49	0.060	66	-0.73	0.62	48	0.45	0.26	35
Cyclopenta(c,d)pyrene	0.11	0.004	13	-0.24	0.09	33	0.06	0.03	14
Benz(a)anthracene	0.27	0.010	25	-0.20	0.14	52	0.13	0.06	33
Chrysene	0.51	0.020	37	-0.27	0.28	63	0.40	0.10	37
Benzofluoranthenes	1.01	0.010	15	-0.02	0.25	49	0.50	0.10	33
Benzo(e)pyrene	-0.23	0.020	39	-0.45	0.25	33	0.55	0.07	09
Benzo(a)pyrene	0.19	0.010	23	-0.42	0.17	56	-0.07	0.07	39
Indeno(1,2,3-c,d)pyrene	0.38	0.006	16	-0.12	0.12	52	0.09	0.05	40
Benzo(g,h,i)perylene	0.81	0.006	06	-0.13	0.18	40	0.21	0.08	30
Coronene	0.59	0.003	03	0.02	0.11	26	0.22	0.04	19

(a) R-Square values are in percent.
(b) Concentration units are in ng/m^3.

Note that pyrene has the highest R-square value among the three potential marker compounds for all compounds except anthracene and benzo(e)pyrene. This indicates that, in general, pyrene appears to be the best marker compound.

SECTION 6

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APPENDIX A

Listing of the Analysis Data Set Containing the Measured Concentration Levels for the Combined 1984 and 1987 Studies

TABLE A-1. LISTING OF THE ANALYSIS DATA SET CONTAINING THE MEASURED CONCENTRATION LEVELS[a] FOR THE COMBINED 1984 AND 1987 STUDIES

1984 Study

OBS	HOUSE	DAY	FURNACE	COOKING	LOCATION	DATE	Cigarettes	Quinoline	Isoquinoline	Phenanthrene	Anthracene
1	A	1	G	G	KIT	3/12	0	1.02	0.87	49.25	2.67
2	A	1	G	G	LR	3/12	0	1.34	1.02	72.02	3.67
3	A	1	G	G	OUT	3/12	.	0.21	0.18	35.88	4.20
4	B	1	G	G	KIT	3/13	0	1.51	1.20	77.23	4.70
5	B	1	G	G	LR	3/13	0	1.63	1.27	88.52	5.81
6	B	1	G	G	OUT	3/13	.	0.28	0.15	36.28	3.62
7	C	1	G	G	KIT	3/13	0	1.36	0.79	58.42	2.74
8	C	1	G	G	LR	3/13	0	1.50	0.95	68.11	2.55
9	C	1	G	G	OUT	3/13	.	0.11	0.17	32.40	1.43
10	C	2	G	G	KIT	3/27	0	0.29	0.69	55.16	2.14
11	C	2	G	G	LR	3/27	0	2.82	1.73	82.49	2.50
12	C	2	G	G	OUT	3/27	.	0.18	0.17	26.57	1.20
13	D	1	G	G	KIT	3/14	18	11.09	4.77	143.58	13.25
14	D	1	G	G	LR	3/14	13	6.26	3.38	124.58	10.52
15	D	1	G	G	OUT	3/14	.	0.88	1.14	75.13	6.41
16	F	1	G	E	KIT	3/19	0	8.09	4.41	112.49	5.01
17	F	1	G	E	LR	3/19	13	31.23	13.63	132.33	8.12
18	F	1	G	E	OUT	3/19	.	0.45	1.54	46.09	3.28
19	F	2	G	E	KIT	3/27	8	13.78	4.46	107.90	5.95
20	F	2	G	E	LR	3/27	4	8.70	3.09	114.88	5.82
21	F	2	G	E	OUT	3/27	.	0.27	1.75	37.55	2.10
22	G	1	E	E	KIT	3/21	0	4.50	0.66	41.63	2.87
23	G	1	E	E	LR	3/21	0	0.51	0.94	50.94	2.73
24	G	1	E	E	OUT	3/21	.	1.62	1.19	33.84	1.36
25	H	1	E	E	KIT	3/21	0	1.22	0.57	34.54	1.48
26	H	1	E	E	LR	3/21	0	1.18	0.52	33.77	1.48
27	H	1	E	E	OUT	3/21	.	0.51	0.42	10.10	0.58
28	I	1	G	G	KIT	3/23	0	1.92	15.50	88.09	72.63
29	I	1	G	G	LR	3/23	0	11.67	6.470	88.060	8.190
30	I	1	G	G	OUT	3/23	.	0.50	0.890	46.450	3.870

(a) Concentration levels are in ng/m^3.

TABLE A-1. LISTING OF THE ANALYSIS DATA SET CONTAINING THE MEASURED CONCENTRATION LEVELS[a] FOR THE COMBINED 1984 AND 1987 STUDIES (Continued)

OBS	Fluoranthene	Pyrene	Cyclopenta(c,d)pyrene	Benz(a)anthracene	Chrysene	Benzofluoranthenes	Benzo(e)pyrene
1	13.00	8.18	0.89	0.89	1.37	1.75	1.03
2	22.54	11.17	0.52	0.67	1.42	1.82	0.98
3	18.35	13.11	3.74	2.69	3.92	4.91	2.88
4	22.64	10.48	0.41	0.75	1.42	1.74	0.89
5	25.17	10.38	0.18	0.64	1.21	1.21	1.03
6	11.85	6.90	0.17	0.90	1.98	2.25	1.16
7	16.22	7.93	0.30	0.44	1.09	1.04	0.81
8	18.36	7.70	0.22	0.46	1.23	1.31	0.75
9	12.09	5.84	0.10	0.67	1.88	2.09	1.09
10	12.98	5.67	0.00	1.03	1.26	1.47	0.88
11	19.67	7.28	0.15	0.89	1.60	1.75	0.84
12	12.31	6.13	0.58	1.07	2.14	2.93	1.38
13	28.37	13.25	1.72	2.77	4.58	3.39	2.24
14	26.11	13.55	1.11	1.47	3.11	2.52	1.31
15	20.71	13.00	0.640	1.82	2.89	3.41	2.05
16	24.28	10.74	0.520	1.01	1.98	2.69	1.92
17	37.37	18.10	0.350	2.25	5.25	5.83	3.12
18	16.90	9.07	0.550	1.11	2.53	3.37	1.85
19	23.09	10.43	0.560	1.23	2.35	1.51	0.90
20	27.61	11.72	0.370	1.25	2.48	2.95	1.56
21	13.74	7.28	0.230	1.12	2.43	3.00	1.59
22	9.77	4.79	0.330	0.26	0.57	0.18	0.00
23	14.78	5.90	0.220	0.81	0.94	0.59	0.31
24	10.64	4.89	0.150	0.23	0.97	1.10	0.74
25	9.23	5.15	0.000	0.30	0.61	0.58	0.24
26	9.84	4.30	0.000	0.31	0.68	0.61	0.35
27	4.75	2.54	0.070	0.23	0.50	0.35	0.29
28	17.32	8.11	0.800	1.18	1.49	1.72	1.01
29	16.73	8.720	0.920	0.98	1.92	1.62	1.07
30	12.14	7.750	0.850	2.77	4.01	8.00	3.08

(a) Concentration levels are in ng/m^3.

TABLE A-1. LISTING OF THE ANALYSIS DATA SET CONTAINING THE MEASURED CONCENTRATION LEVELS[a] FOR THE COMBINED 1984 AND 1987 STUDIES (Continued)

OBS	Benzo(a)pyrene	Indeno(1,2,3-c,d)pyrene	Benzo(g,h,i)perylene	Coronene	Air Exchange Rate	Total Extractable[b] Organic Mass
1	0.94	0.89	1.75	1.67	0.340136	0.031528
2	1.07	0.83	1.40	1.00	0.340136	0.054612
3	2.85	2.47	5.10	3.60	0.340136	0.012952
4	0.97	0.81	1.40	0.99	0.349650	0.066212
5	0.67	0.48	0.82	0.30	0.349650	0.072304
6	0.73	0.89	1.82	1.03	0.349650	0.029245
7	0.69	0.72	1.02	0.58	0.289855	0.059130
8	0.55	0.61	0.89	0.36	0.289855	0.104417
9	0.63	0.93	1.33	0.98	0.289855	0.039164
10	0.94	0.59	0.98	0.69	0.289855	0.058528
11	0.67	0.72	0.97	0.67	0.289855	0.074666
12	1.24	1.09	1.69	0.91	0.289855	0.008796
13	2.65	2.60	3.15	1.94	0.210084	0.258742
14	1.58	1.21	1.88	1.19	0.210084	0.112458
15	1.94	1.65	3.82	2.39	0.210084	0.038171
16	1.57	1.18	2.75	3.08	0.740741	0.051275
17	3.33	2.58	2.77	0.91	0.740741	0.082421
18	1.70	1.07	2.49	1.26	0.740741	0.024423
19	0.96	1.13	1.35	0.92	0.319489	0.113578
20	0.90	1.21	1.50	0.90	0.319489	0.080062
21	1.17	1.07	1.72	0.85	0.319489	0.017084
22	0.00	0.00	0.00	0.00	0.671141	0.036896
23	0.00	0.49	0.45	0.00	0.671141	0.044141
24	0.00	0.37	0.84	0.40	0.671141	0.014289
25	0.00	0.16	0.49	0.22	0.689655	0.070132
26	0.28	0.30	0.48	0.28	0.689655	0.070368
27	0.20	0.18	0.29	0.22	0.689655	0.007722
28	0.69	0.60	1.78	1.55	0.370370	0.301672
29	0.94	0.96	2.65	2.80	0.370370	0.0920026
30	3.17	2.69	4.75	2.67	0.370370	0.0402216

(a) Concentration levels are in ng/m^3.

(b) Concentration levels are in mg/m^3.

TABLE A-1. LISTING OF THE ANALYSIS DATA SET CONTAINING THE MEASURED CONCENTRATION LEVELS[a] FOR THE COMBINED 1984 AND 1987 STUDIES (Continued)

1987 Study

OBS	HOUSE	DAY	FURNACE	COOKING	LOCATION	DATE	Cigarettes	Quinoline	Isoquinoline	Phenanthrene	Anthracene
31	1	1	G	E	KIT	3/14	0	8.50	12.0	55	1.80
32	1	1	G	E	LR	3/14	0	9.40	21.0	71	5.00
33	1	1	G	E	OUT	3/14	.	4.20	14.0	35	0.92
34	2	1	G	G	KIT	3/15	10	84.00	55.0	56	5.30
35	2	1	G	G	LR	3/15	16	240.00	140.0	87	11.00
36	2	1	G	G	OUT	3/15	.	2.40	5.1	29	1.50
37	3	1	E	E	KIT	3/17	6	84.00	40.0	94	5.00
38	3	1	E	E	LR	3/17	9	76.00	34.0	80	4.60
39	3	1	E	E	OUT	3/17	.	0.78	4.3	17	0.55
40	3	2	E	E	KIT	4/04	4	120.00	47.0	80	2.80
41	3	2	E	E	LR	4/04	0	91.00	36.0	61	1.70
42	3	2	E	E	OUT	4/04	.	5.50	4.5	23	2.00
43	4	1	G	G	KIT	3/18	7	170.00	110.0	170	7.20
44	4	1	G	G	LR	3/18	15	480.00	300.0	200	12.00
45	4	1	G	G	OUT	3/18	.	3.40	11.0	34	0.83
46	5	1	G	E	KIT	3/20	11	640.00	340.0	130	8.00
47	5	1	G	E	LR	3/20	20	1100.00	620.0	210	15.00
48	5	1	G	E	OUT	3/20	.	4.00	12.0	54	1.60
49	6	1	G	E	KIT	3/23	9	180.00	89.0	78	4.00
50	6	1	G	E	LR	3/23	12	300.00	170.0	110	6.00
51	6	1	G	E	OUT	3/23	.	2.50	4.9	22	0.28
52	7	1	E	E	KIT	3/25	0	28.00	67.0	55	1.50
53	7	1	E	E	LR	3/25	0	23.0000	35.00	59	2.000
54	7	1	E	E	OUT	3/25	.	2.5000	10.00	29	0.640
55	8	1	G	G	KIT	3/26	0	11.0000	8.10	140	3.500
56	8	1	G	G	LR	3/26	0	9.1000	16.00	88	0.780
57	8	1	G	G	OUT	3/26	.	3.0000	9.60	28	0.460
58	8	2	G	G	KIT	3/27	0	9.0000	18.00	100	3.000
59	8	2	G	G	LR	3/27	0	13.0000	19.00	110	1.700
60	8	2	G	G	OUT	3/27	.	4.6000	17.00	48	0.780

(a) Concentration levels are in ng/m^3.

TABLE A-1. LISTING OF THE ANALYSIS DATA SET CONTAINING THE MEASURED CONCENTRATION LEVELS[a] FOR THE COMBINED 1984 AND 1987 STUDIES (Continued)

OBS	Fluoranthene	Pyrene	Cyclopenta(c,d)pyrene	Benz(a)anthracene	Chrysene	Benzofluoranthenes	Benzo(e)pyrene
31	7.4	4.9	0.14	0.39	0.86	1.20	0.55
32	7.6	4.6	0.12	0.29	0.75	0.74	0.49
33	6.5	3.8	0.09	0.42	1.00	1.40	0.56
34	5.8	3.9	0.34	0.70	1.60	1.70	1.50
35	8.6	5.2	1.10	1.40	2.60	2.50	3.20
36	6.0	5.1	0.17	0.60	1.40	1.70	0.89
37	8.1	5.0	0.20	0.45	1.30	1.00	2.50
38	6.5	4.0	0.20	0.33	0.94	0.92	1.30
39	3.0	1.9	0.09	0.22	0.59	0.64	0.28
40	7.2	4.7	0.23	0.34	0.91	0.71	1.10
41	5.1	3.3	0.17	0.17	0.48	0.51	0.57
42	5.1	3.9	0.08	0.83	1.40	1.50	0.84
43	18.0	11.0	0.35	0.66	1.40	1.20	1.10
44	19.0	11.0	0.87	1.60	3.50	2.70	3.70
45	6.4	4.9	0.18	0.83	1.60	2.30	0.88
46	14.0	11.0	1.30	1.60	3.70	2.90	4.50
47	23.0	17.0	2.00	3.40	7.20	5.10	10.00
48	9.4	9.4	0.34	0.58	2.20	1.40	0.83
49	7.6	5.7	0.24	0.35	1.10	0.83	0.89
50	6.4	9.5	0.85	1.40	2.40	2.00	6.50
51	3.9	3.4	0.12	0.18	0.82	0.61	0.24
52	6.2	3.6	0.18	0.25	0.58	0.58	0.33
53	7.2	5.6	0.190	0.24	0.93	0.78	0.680
54	4.3	5.1	0.190	0.23	1.10	0.51	0.280
55	23.0	14.0	0.400	0.43	1.60	1.50	0.880
56	12.0	7.4	0.290	1.00	1.20	2.50	1.400
57	4.8	2.3	0.050	0.14	0.38	0.48	0.210
58	13.0	7.4	0.140	0.34	1.40	1.80	0.710
59	14.0	8.8	0.130	0.41	2.00	2.50	1.200
60	7.0	3.5	0.090	0.20	0.81	0.74	0.290

(a) Concentration levels are in ng/m3.

TABLE A-1. LISTING OF THE ANALYSIS DATA SET CONTAINING THE MEASURED CONCENTRATION LEVELS[a] FOR THE COMBINED 1984 AND 1987 STUDIES (Continued)

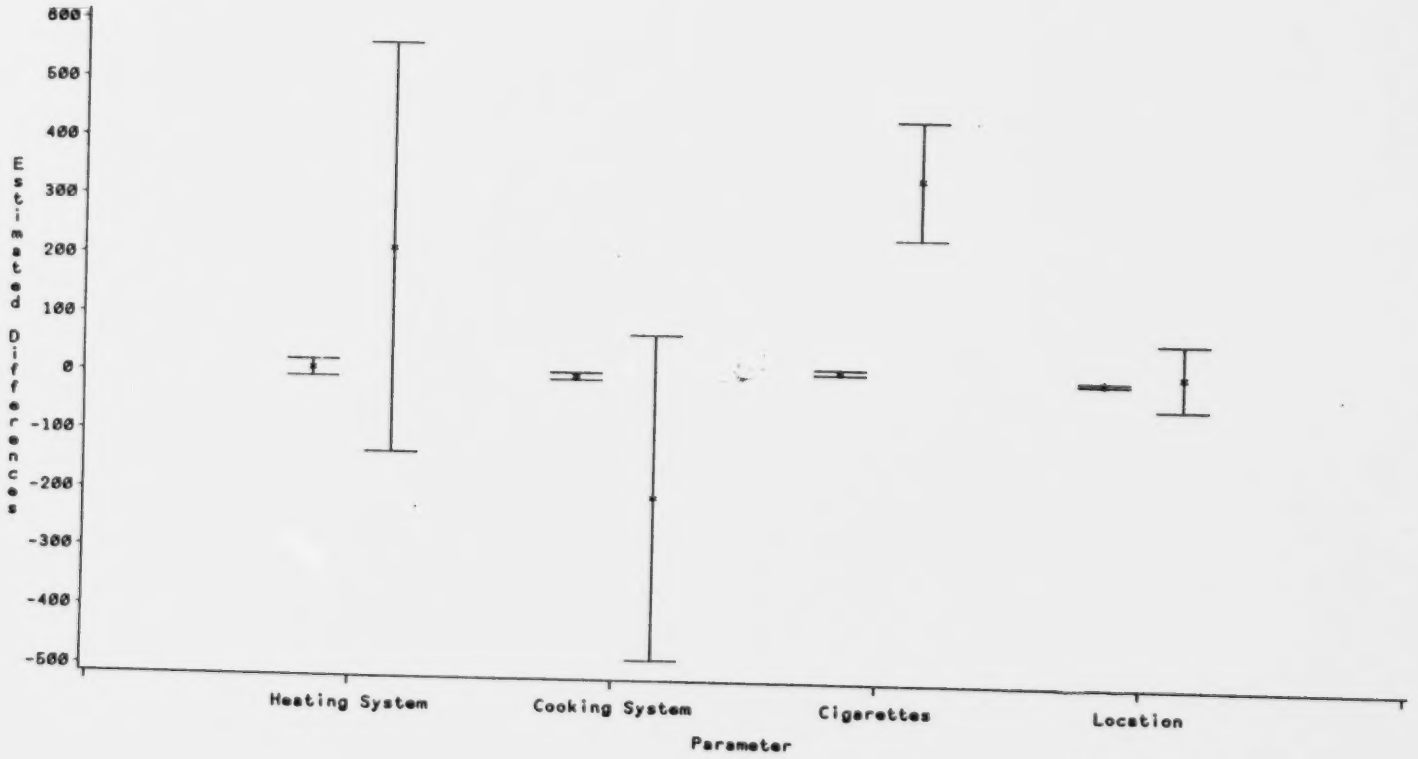
OBS	Benzo(a)pyrene	Indeno(1,2,3-c,d)pyrene	Benzo(g,h,i)perylene	Coronene	Air Exchange Rate	Total Extractable Organic Mass[b]
31	0.25	0.44	0.88	0.44	1.98	0.0680
32	0.28	0.35	0.51	0.37	1.98	0.0640
33	0.29	0.48	0.60	0.39	1.98	0.0160
34	0.62	0.63	0.84	0.55	1.71	0.1700
35	1.20	0.97	1.40	0.60	1.71	0.1600
36	0.31	0.51	0.74	0.48	1.71	0.0180
37	0.58	0.35	0.50	0.17	0.18	0.1200
38	0.34	0.40	0.51	0.33	0.18	0.1100
39	0.20	0.17	0.23	0.10	0.18	0.0110
40	0.30	0.34	0.71	0.50	0.50	0.1300
41	0.29	0.30	0.41	0.25	0.50	0.0770
42	0.22	0.44	0.46	0.17	0.50	0.0130
43	0.60	0.74	1.10	1.10	1.14	0.1200
44	1.40	1.00	1.60	0.64	1.14	0.2800
45	0.54	0.74	1.10	0.59	1.14	0.0120
46	1.60	1.00	1.40	1.40	0.72	0.4000
47	3.30	1.80	2.50	0.64	0.72	0.5700
48	0.30	0.43	0.81	0.68	0.72	0.0470
49	0.32	0.18	0.39	0.19	0.89	0.1700
50	1.40	1.30	1.40	1.40	0.89	0.2800
51	0.10	0.16	0.20	0.09	0.89	0.0190
52	0.28	0.31	0.55	0.68	0.38	0.0790
53	0.310	0.24	0.32	0.310	0.380	0.1500
54	0.150	0.18	0.27	0.180	0.380	0.0240
55	0.310	0.40	0.48	0.230	0.200	0.2900
56	0.830	1.00	1.10	0.810	0.200	0.1300
57	0.140	0.23	0.28	0.260	0.200	0.0091
58	0.490	0.48	0.66	0.260	0.200	0.1300
59	0.870	0.70	0.74	0.480	0.200	0.1700
60	0.130	0.28	0.44	0.320	0.200	0.0120

(a) Concentration levels are in ng/m^3.

(b) Concentration levels are in mg/m^3.

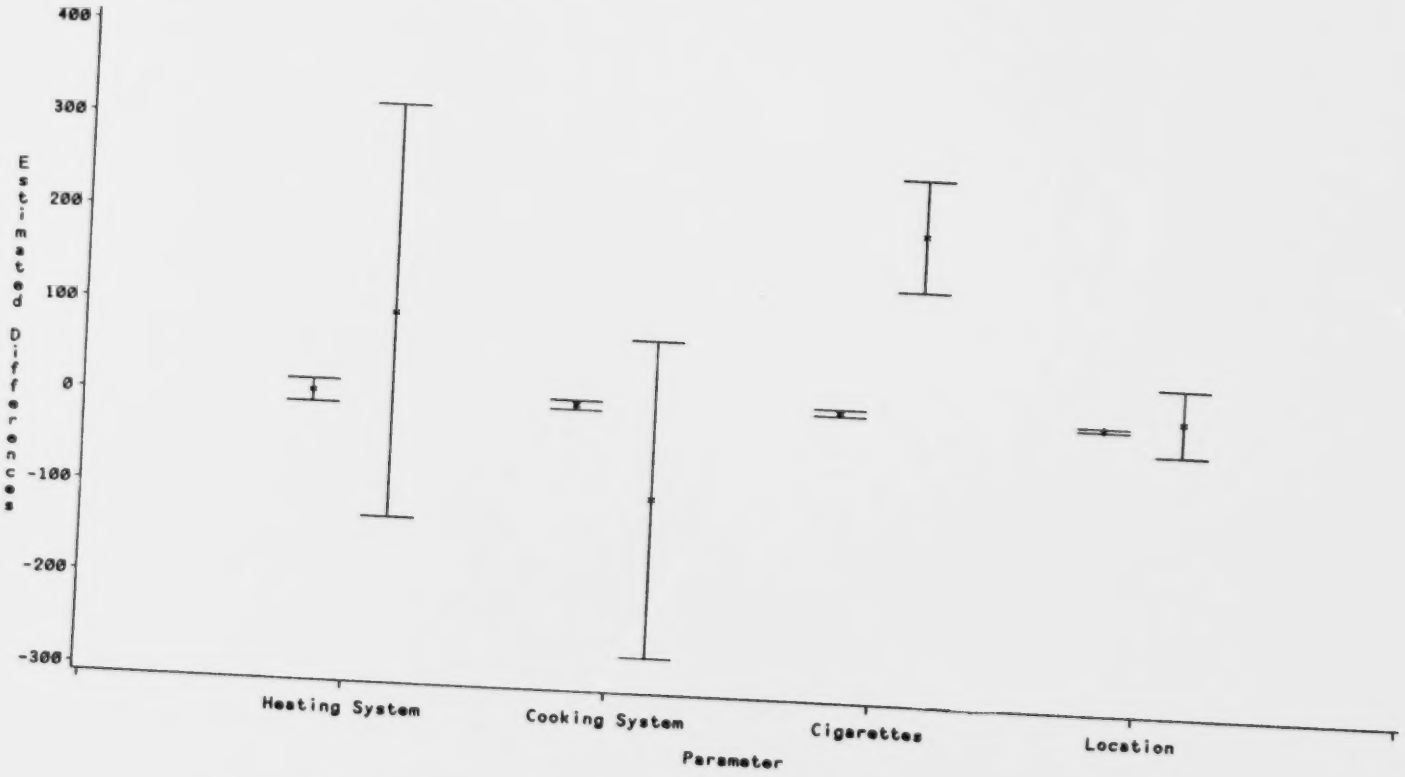
APPENDIX B

Comparison of 1984 and 1987 Modeling Results on the Contributions of Indoor Combustion Sources to Indoor PAH Concentration Levels



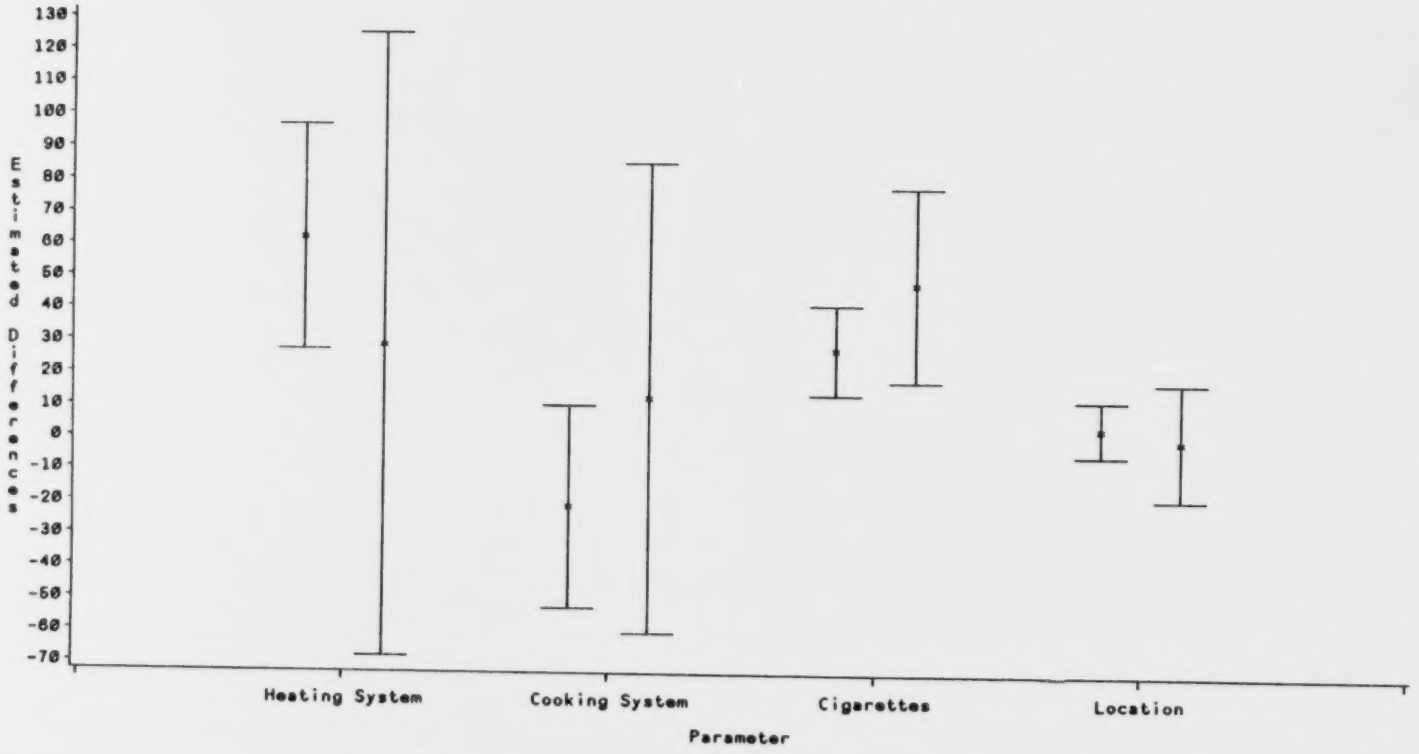
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-1. Estimated Differences (and 95% Confidence Intervals) in Average Quinoline Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



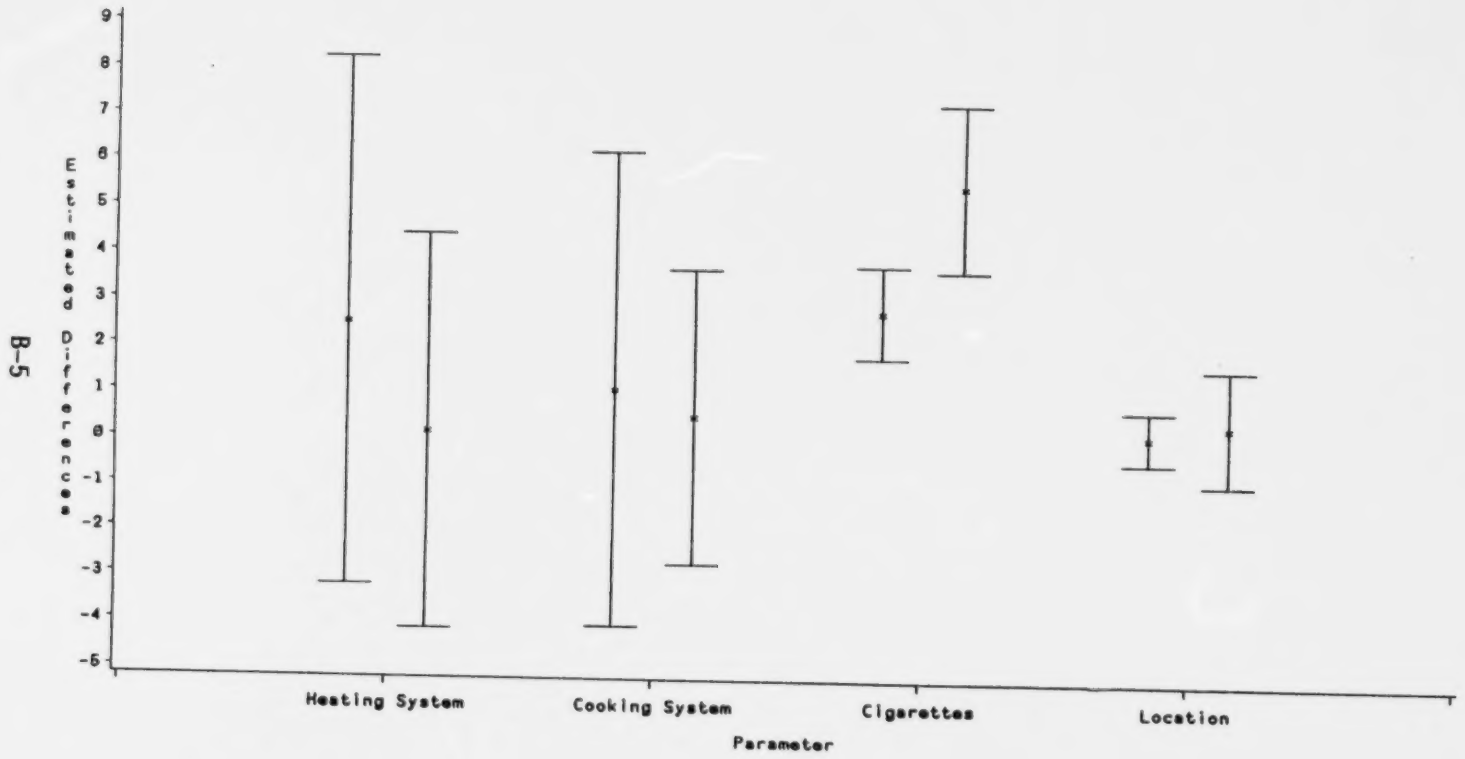
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-2. Estimated Differences (and 95% Confidence Intervals) in Average Isoquinoline Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



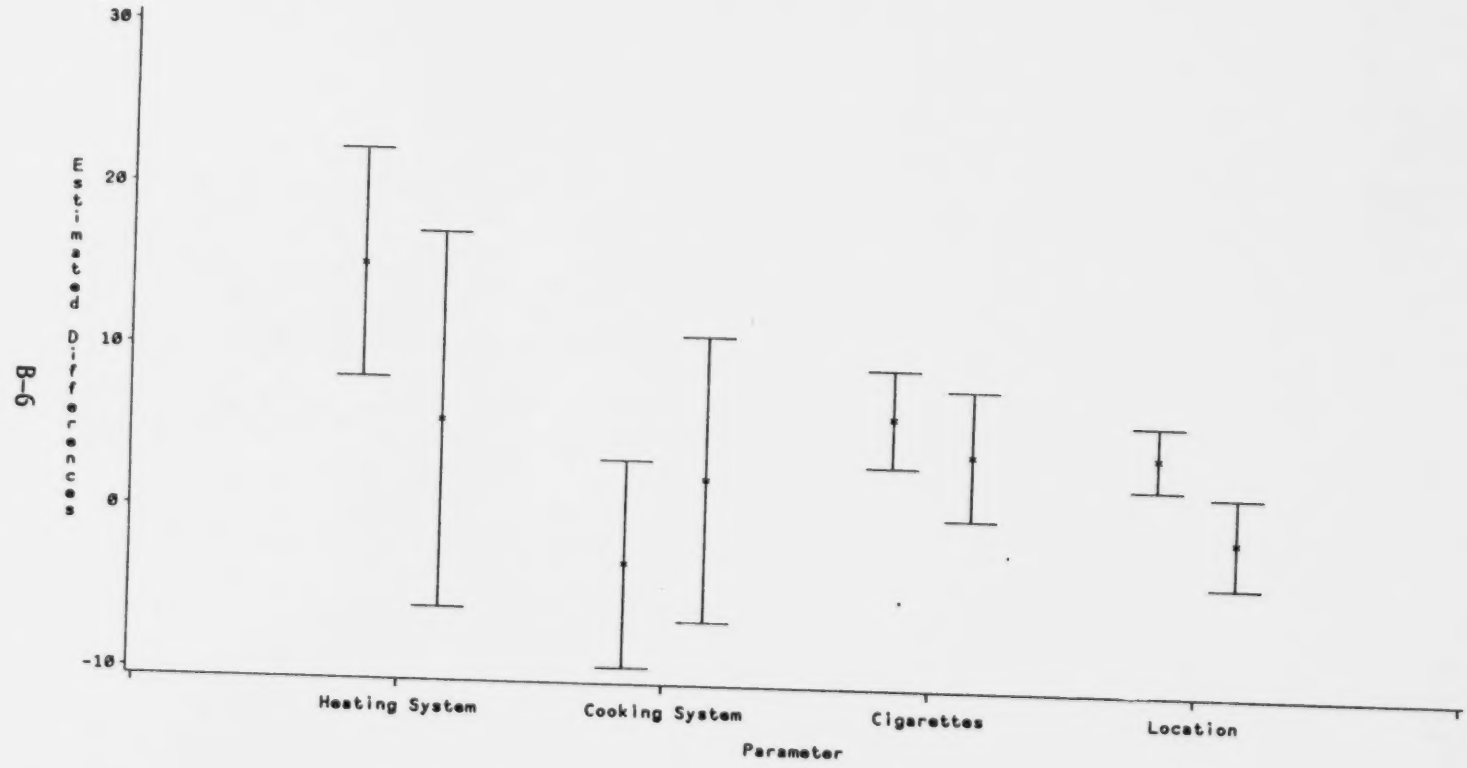
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-3. Estimated Differences (and 95% Confidence Interval) in Average Phenanthrene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



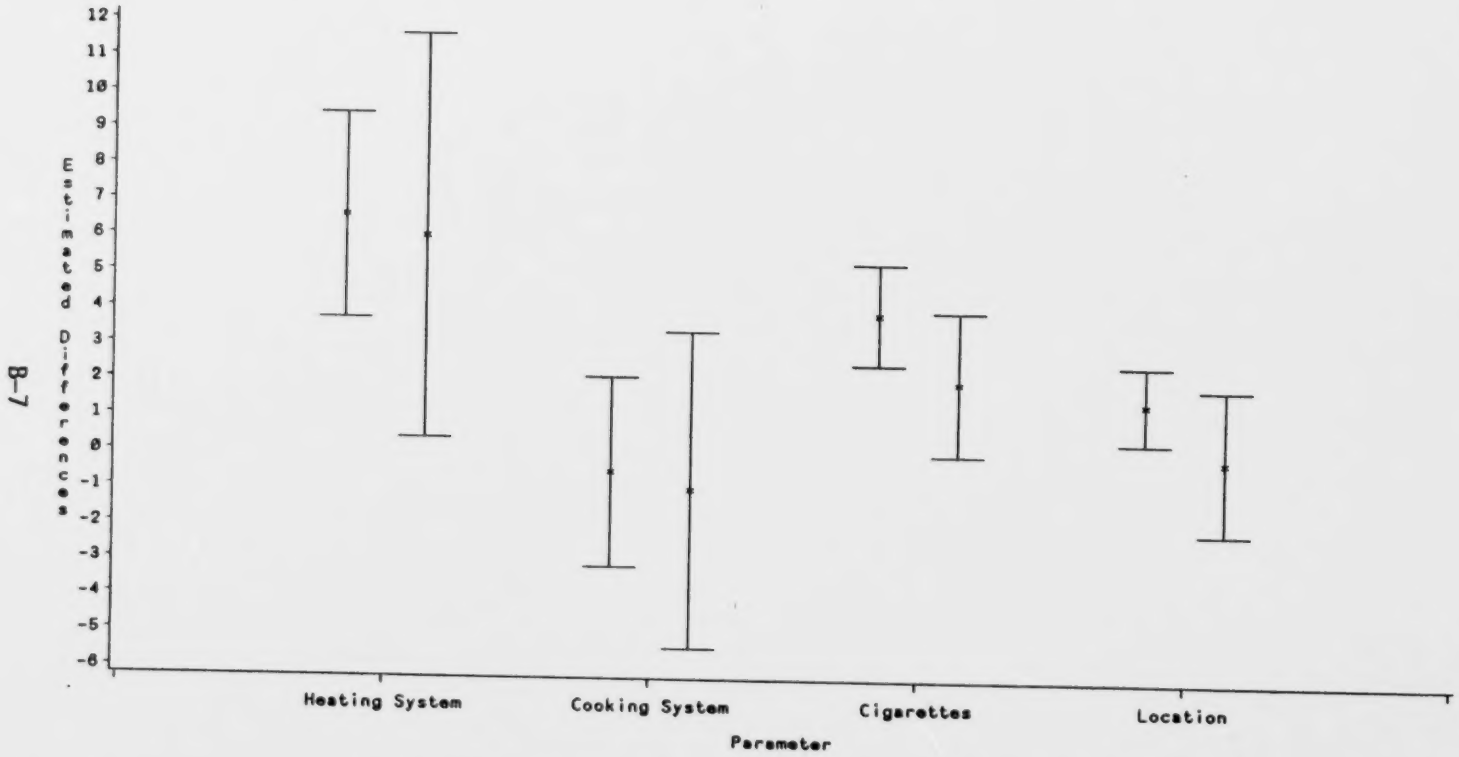
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-4. Estimated Differences (and 95% Confidence Interval) in Average Anthracene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m^3).



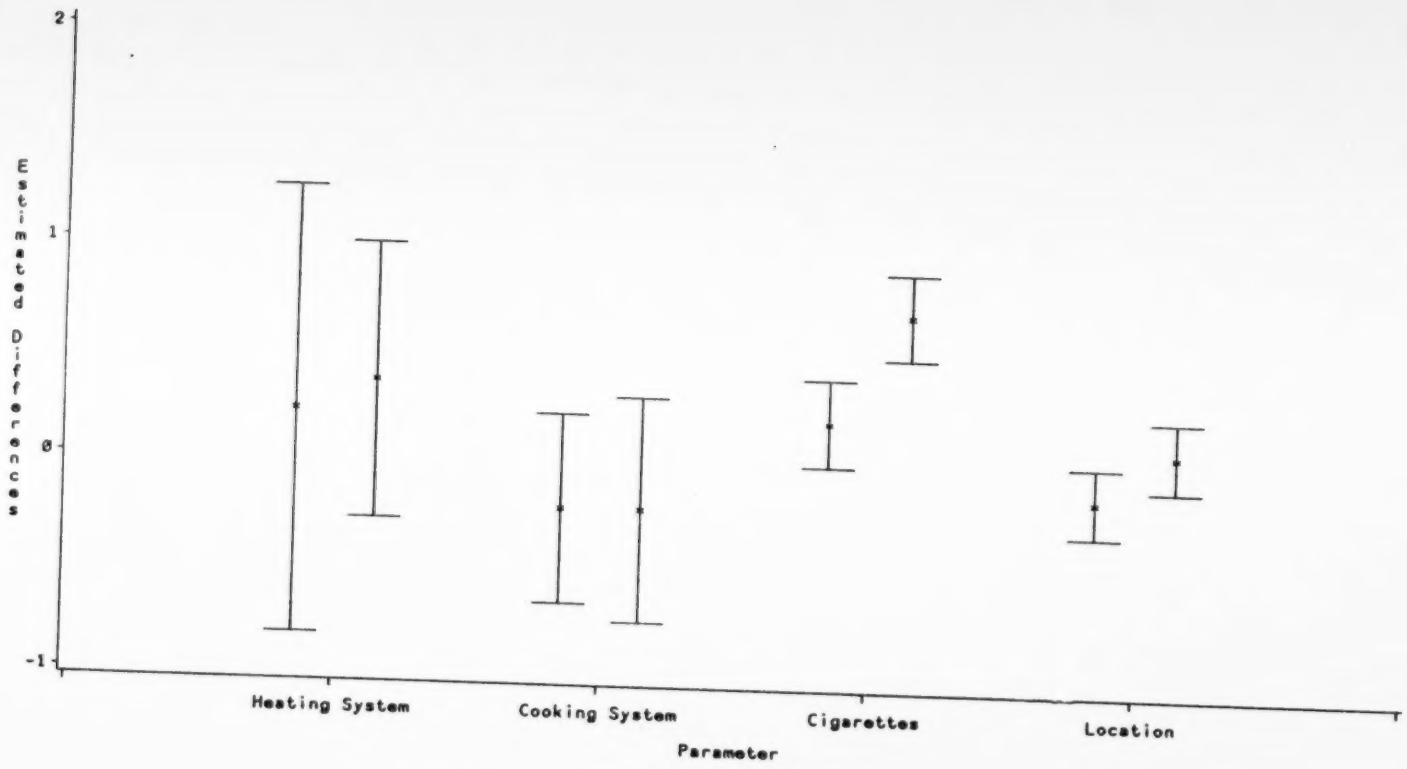
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-5. Estimated Differences (and 95% Confidence Interval) in Average Fluoranthene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m^3).



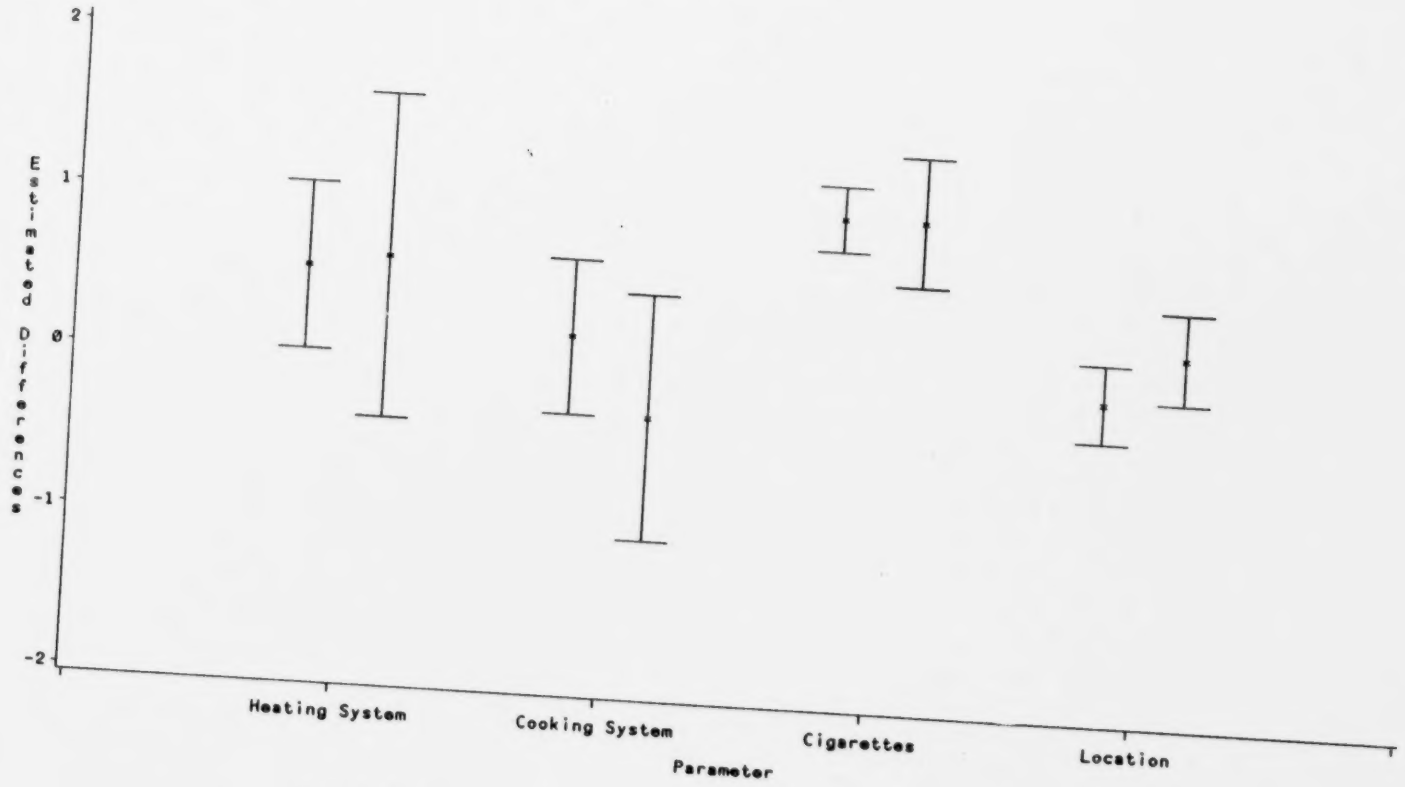
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-6. Estimated Differences (and 95% Confidence Interval) in Average Pyrene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



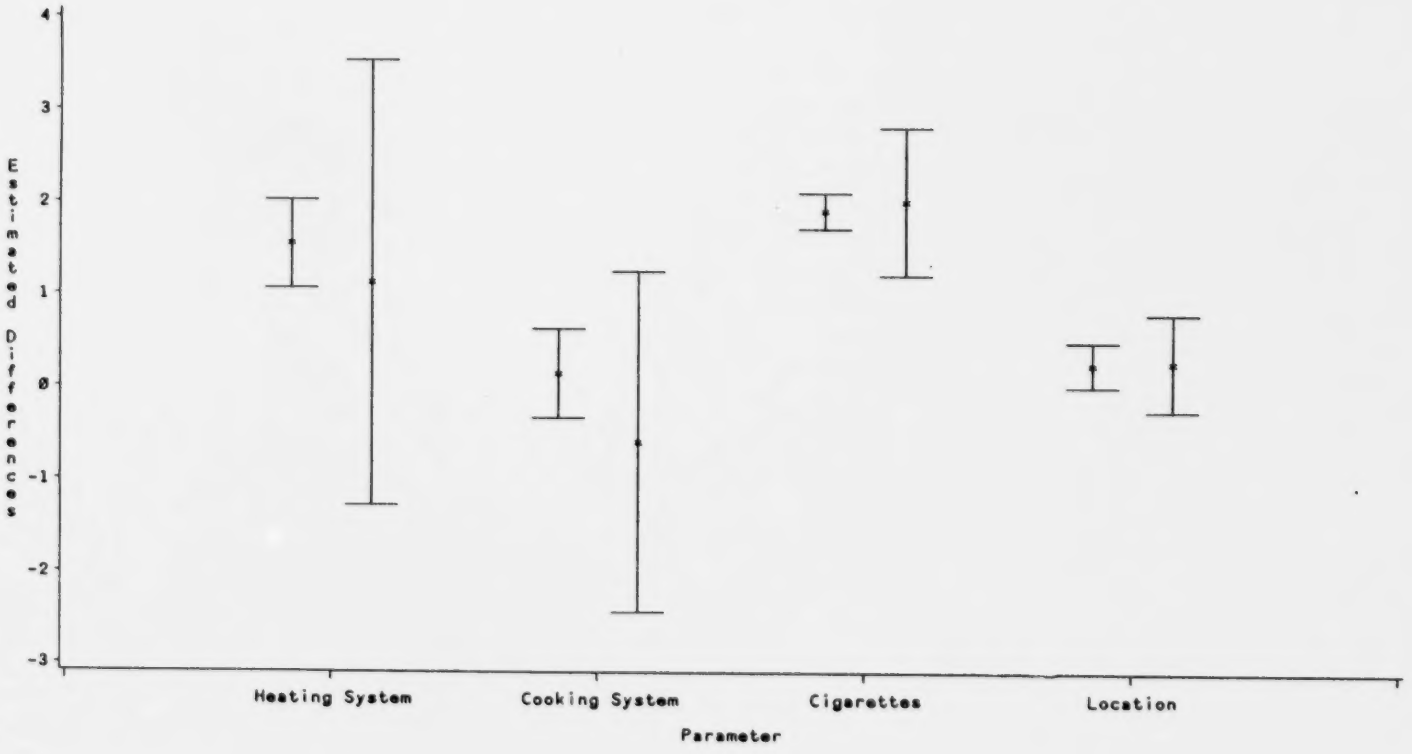
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-7. Estimated Differences (and 95% Confidence Interval) in Average Cyclopenta(c,d)pyrene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



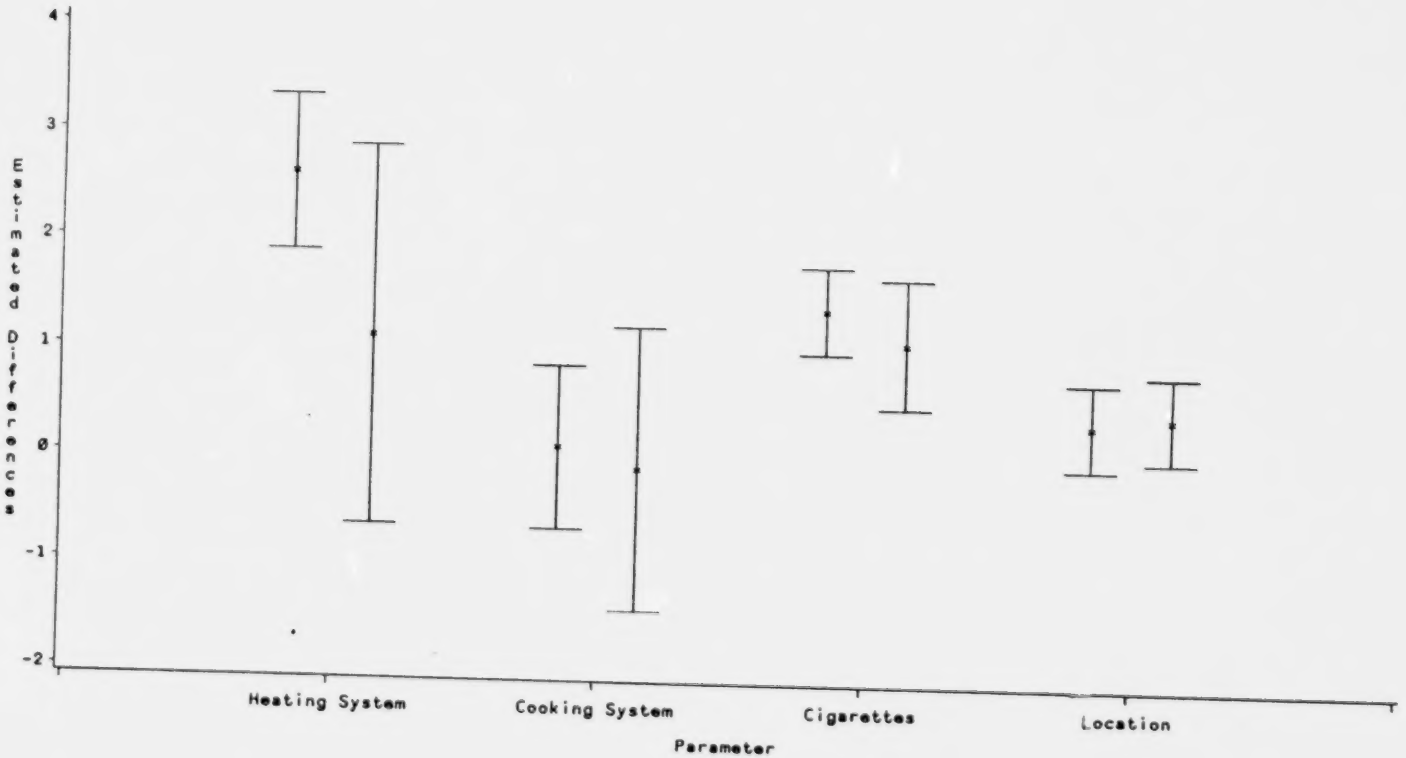
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-8. Estimated Differences (and 95% Confidence Interval) in Average Benz(a)anthracene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



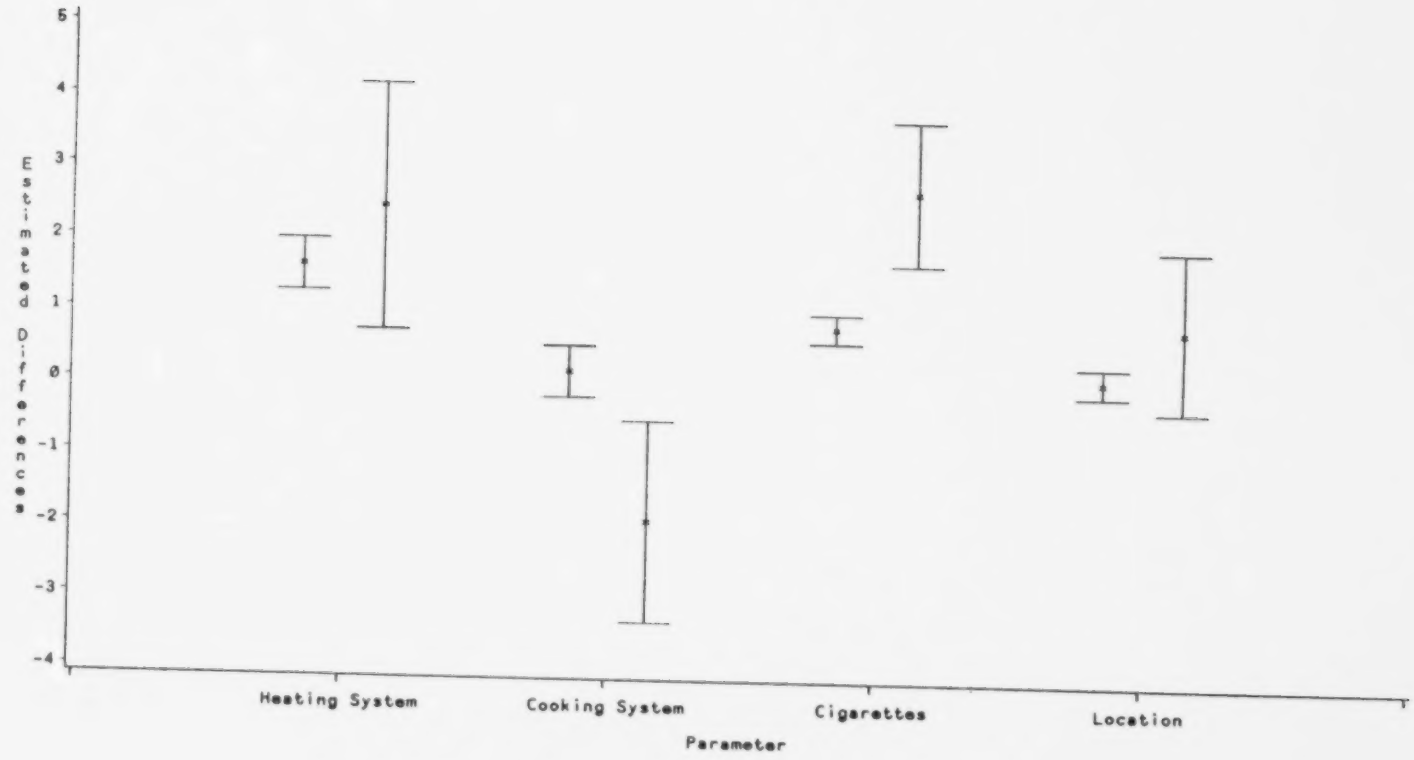
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-9. Estimated Differences (and 95% Confidence Interval) in Average Chrysene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



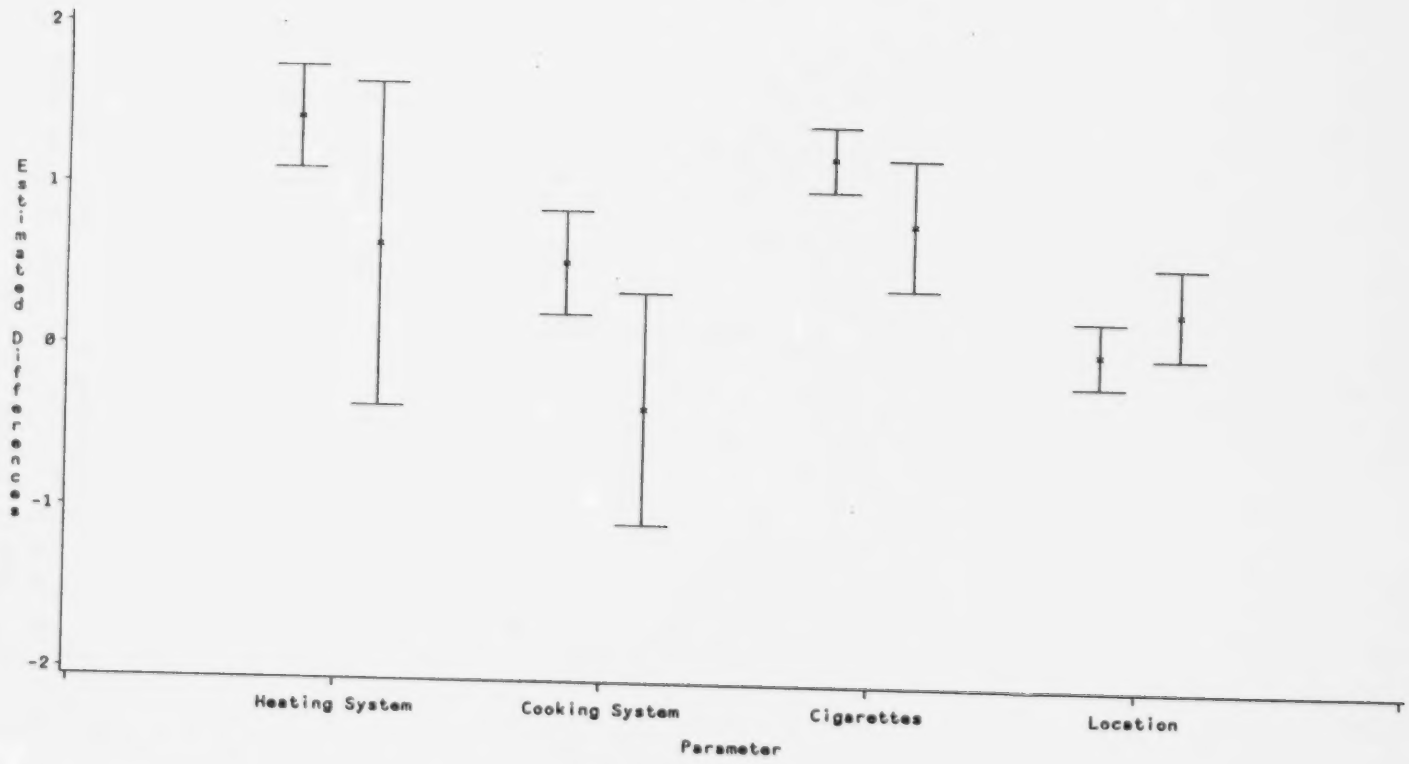
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-10. Estimated Differences (and 95% Confidence Interval) in Average Benzofluoranthenes Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



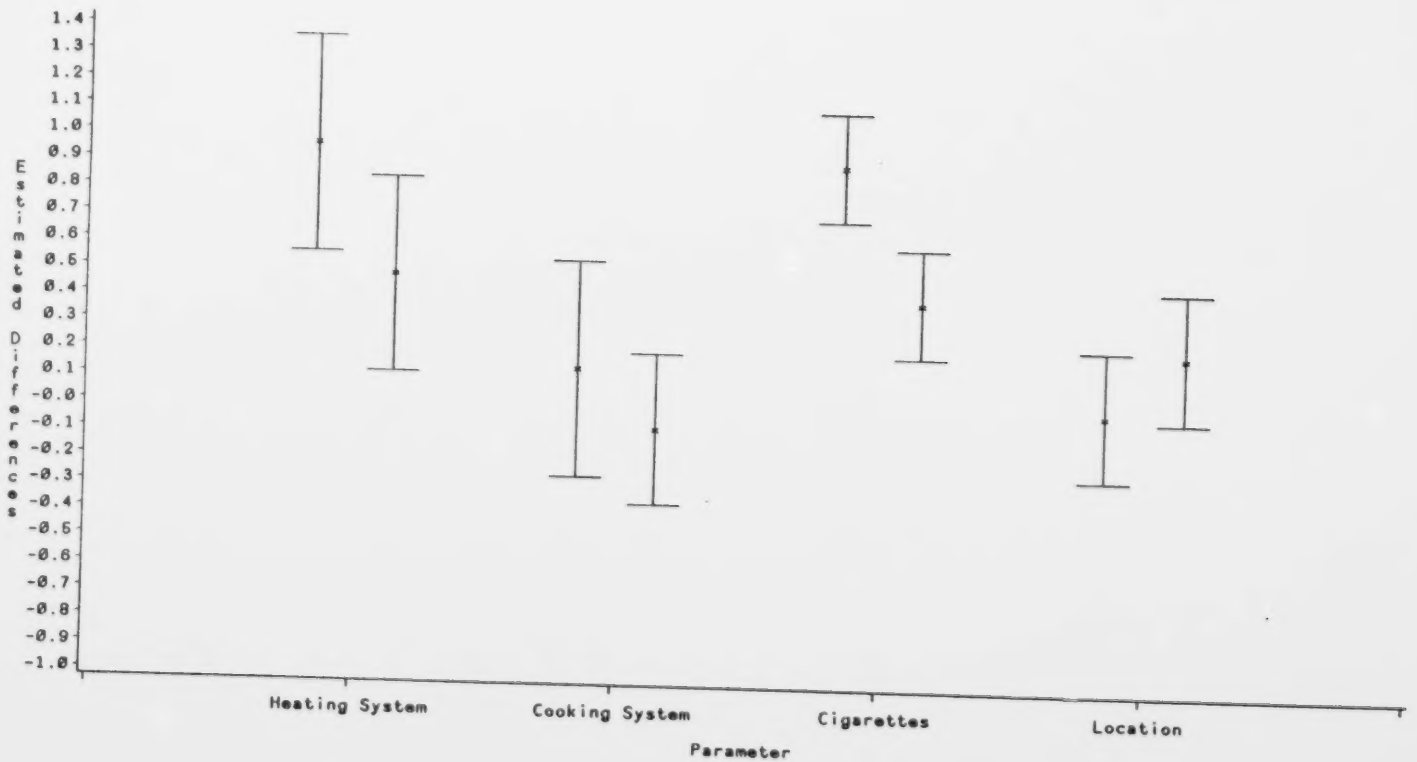
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-11. Estimated Differences (and 95% Confidence Interval) in Average Benzo(e)pyrene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



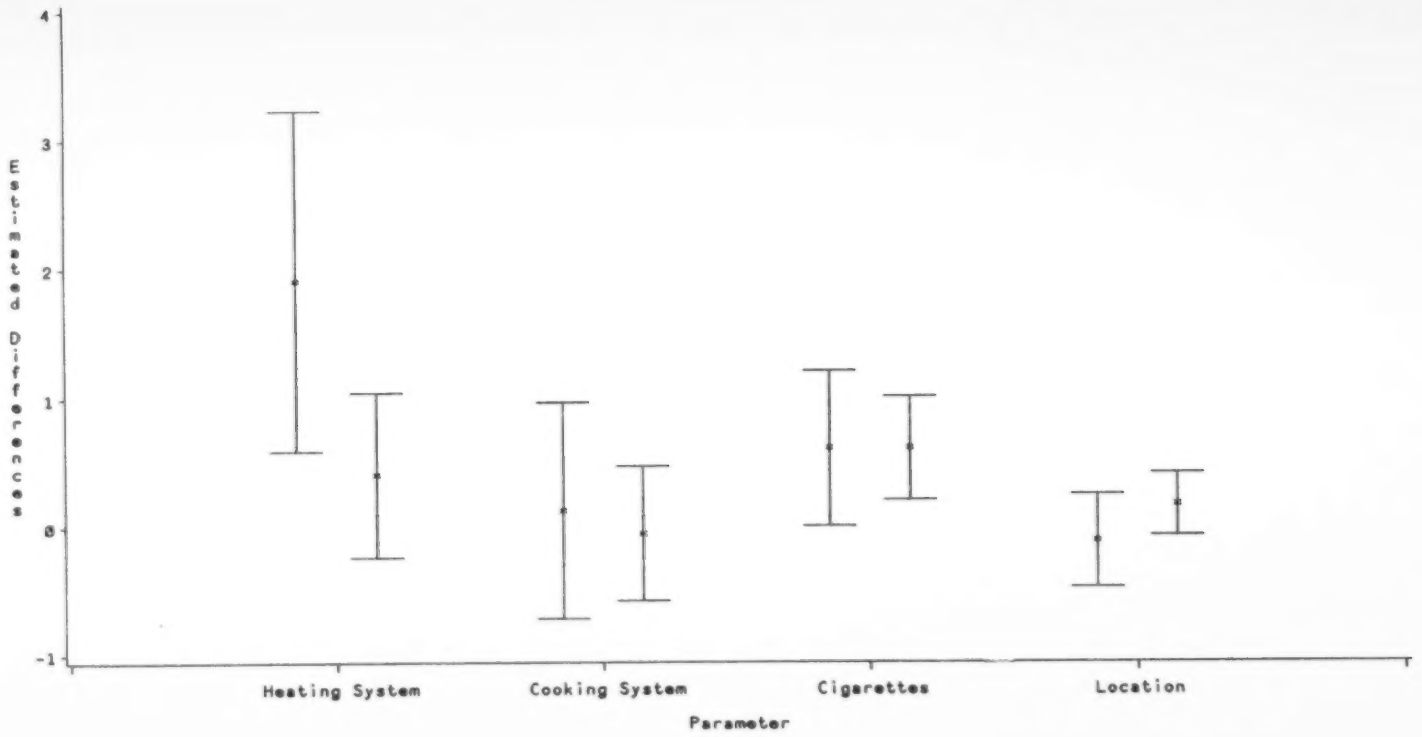
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-12. Estimated Differences (and 95% Confidence Interval) in Average Benzo(a)pyrene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



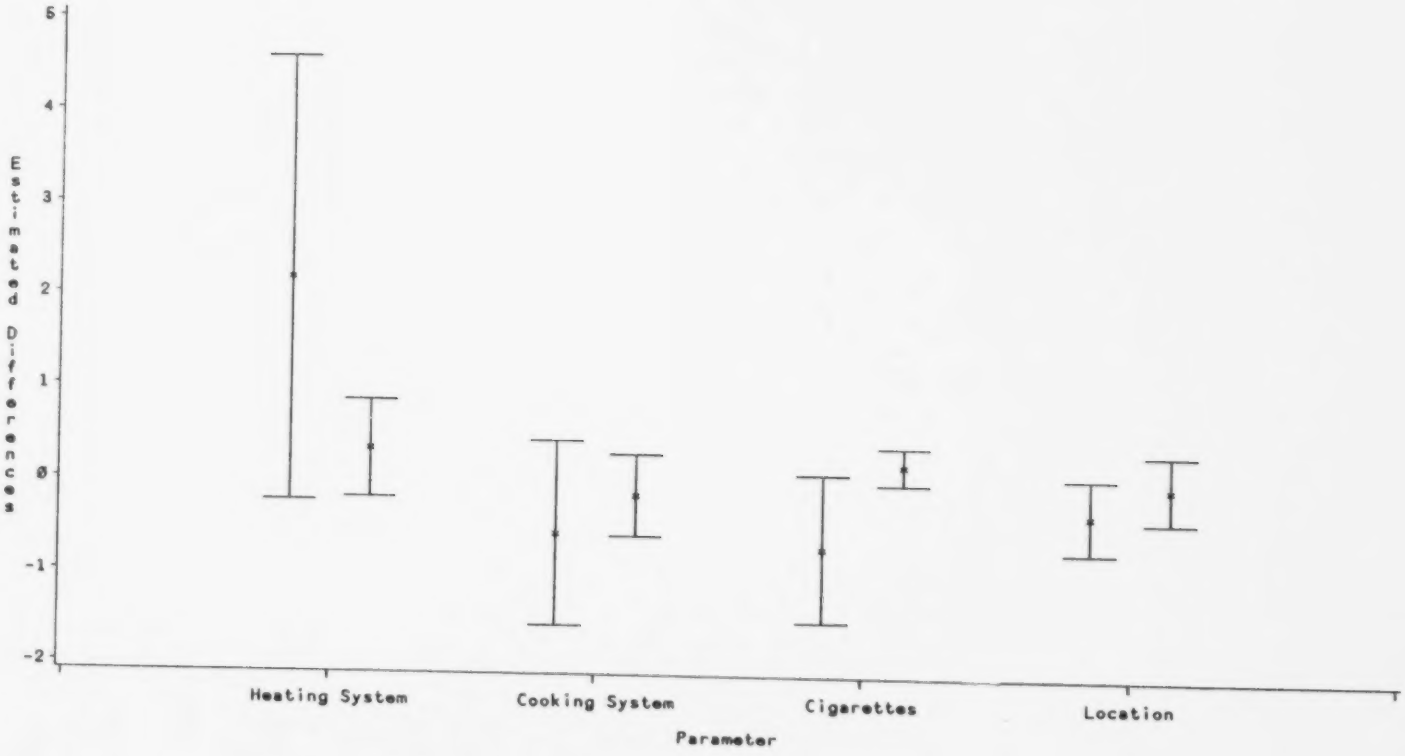
The left bar is for the 1984 study, the right for the 1987 study.

Figure B-13. Estimated Differences (and 95% Confidence Interval) in Average Indeno(1,2,3-c,d)perylene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



The left bar is for the 1984 study, the right for the 1987 study.

Figure B-14. Estimated Differences (and 95% Confidence Interval) in Average Benzo(g,h,i)perylene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m3).



The left bar is for the 1984 study, the right for the 1987 study.

Figure B-15. Estimated Differences (and 95% Confidence Interval) in Average Coronene Levels Due to Comparison of 1984 and 1987 Estimates (ng/m^3).

The left bar is for the 1984 study, the right for the 1987 study.

Figure B-16. Estimated Differences (and 95% Confidence Interval) in Average Total Extractable Organic Mass Levels Due to Comparison of 1984 and 1987 Estimates (mg/m3).

TABLE B-1. A COMPARISON OF ESTIMATED DIFFERENCES IN AVERAGE CONCENTRATION LEVELS (LCL) AND UPPER (UCL) 95% CONFIDENCE LIMITS FOR THE TRUE DIFFERENCE DUE TO EACH EXPERIMENTAL FACTOR

SAS

COMPOUND=Quinoline — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	8.90	13.50	18.10	240	340	440
COOKING	-5.90	0.34	6.58	-480	-204	72
HEATING	-5.40	8.72	22.84	-134	214	562
LOCATION	-0.94	1.46	3.86	-42	14	70

COMPOUND=Isoquinoline — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	1.50	5.10	8.70	140	200	260
COOKING	-3.84	1.32	6.28	-270	-98	74
HEATING	-6.54	5.66	17.86	-130	84	318
LOCATION	-2.22	-0.30	1.62	-28	10	46

COMPOUND=Phenanthrene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	13.80	27.60	41.40	18.00	48.00	78.00
COOKING	-52.40	-21.04	10.32	-60.20	12.60	85.40
HEATING	27.38	62.22	97.06	-67.60	28.80	125.20
LOCATION	-4.66	3.74	12.34	-18.08	-0.08	17.92

COMPOUND=Anthracene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	1.80	2.80	3.80	3.70	5.50	7.30
COOKING	-4.04	1.08	6.20	-2.70	0.50	3.70
HEATING	-3.20	2.52	8.24	-4.12	0.16	4.44
LOCATION	-0.40	0.16	0.72	-0.84	0.40	1.64

COMPOUND=Fluoranthene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	3.20	6.2	9.20	0.0	4.0	8.0
COOKING	-8.80	-3.1	3.30	-6.6	2.2	11.0
HEATING	8.18	15.2	22.24	-8.0	5.6	17.2
LOCATION	2.14	4.1	6.06	-3.8	-1.0	1.8

TABLE B-1. A COMPARISON OF ESTIMATED DIFFERENCES IN AVERAGE CONCENTRATION LEVELS (LCL) AND UPPER (UCL) 95% CONFIDENCE LIMITS FOR THE TRUE DIFFERENCE DUE TO EACH EXPERIMENTAL FACTOR (Continued)

SAS

COMPOUND=Pyrene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	2.50	3.80	5.30	0.0	2.0	4.0
COOKING	-3.18	-0.52	2.12	-5.4	-1.0	3.4
HEATING	3.74	6.58	9.42	0.4	6.0	11.6
LOCATION	0.38	1.46	2.54	-2.1	-0.1	1.9

COMPOUND=Cyclopenta(c,d)pyrene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	0.00	0.20	0.40	0.50	0.70	0.90
COOKING	-0.22	0.22	0.66	-0.74	-0.22	0.30
HEATING	-0.82	0.22	1.26	-0.28	0.36	1.00
LOCATION	-0.02	0.14	0.30	-0.08	0.08	0.24

COMPOUND=Benz(a)anthracene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	0.80	1.00	1.20	0.60	1.00	1.40
COOKING	-0.30	0.18	0.66	-1.06	-0.30	0.46
HEATING	0.02	0.54	1.06	-0.38	0.62	1.62
LOCATION	-0.18	0.06	0.30	-0.04	0.24	0.52

COMPOUND=Chrysene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	1.70	1.90	2.10	1.20	2.00	2.80
COOKING	-0.34	0.14	0.62	-2.44	-0.80	1.24
HEATING	1.06	1.54	2.02	-1.28	1.12	3.52
LOCATION	0.00	0.24	0.48	-0.26	0.26	0.78

COMPOUND=Benzofluoranthenes — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	1.00	1,40	1.80	0.50	1.10	1.70
COOKING	-0.66	0.10	0.86	-1.42	-0.10	1.22
HEATING	1.90	2.62	3.34	-0.64	1.12	2.88
LOCATION	-0.04	0.36	0.76	0.04	0.44	0.84

TABLE B-1. A COMPARISON OF ESTIMATED DIFFERENCES IN AVERAGE CONCENTRATION LEVELS (LCL) AND UPPER (UCL) 95% CONFIDENCE LIMITS FOR THE TRUE DIEFERENCE DUE TO EACH EXPERIMENTAL FACTOR (Continued)

SAS

COMPOUND=Benzo(e)pyrene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	0.60	0.80	1.00	1.70	2.70	3.70
COOKING	-0.20	0.16	0.52	-3.32	-1.92	-0.52
HEATING	1.26	1.62	1.98	0.72	2.44	4.16
LOCATION	-0.10	0.10	0.30	-0.30	0.82	1.94

COMPOUND=Benzo(a)pyrene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	1.00	1.20	1.40	0.40	0.80	1.20
COOKING	0.22	0.54	0.86	-1.08	-0.36	0.36
HEATING	1.10	1.42	1.74	-0.36	0.64	1.64
LOCATION	-0.18	0.02	0.22	0.00	0.28	0.56

COMPOUND=Indeno(1,2,3-c,d)perylene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	0.70	0.90	1.10	0.20	0.40	0.60
COOKING	-0.26	0.14	0.54	-0.38	-0.08	0.20
HEATING	0.58	0.98	1.38	0.12	0.48	0.84
LOCATION	-0.24	0.00	0.24	-0.02	0.22	0.46

COMPOUND=Benzo(g,h,i)perylene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	0.00	0.60	1.20	0.20	0.60	1.00
COOKING	-0.72	0.12	0.96	-0.58	-0.08	0.46
HEATING	0.58	1.90	3.22	-0.24	0.40	1.04
LOCATION	-0.48	-0.12	0.24	-0.08	0.16	0.40

COMPOUND=Coronene — ng/m^3

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	-1.50	-0.70	0.10	0.00	0.20	0.40
COOKING	-1.56	-0.56	0.44	-0.58	-0.14	0.30
HEATING	-0.22	2.18	4.58	-0.18	0.34	0.86
LOCATION	-0.72	-0.32	0.08	-0.38	-0.02	0.34

TABLE B-1. A COMPARISON OF ESTIMATED DIFFERENCES IN AVERAGE CONCENTRATION LEVELS (LCL) AND UPPER (UCL) 95% CONFIDENCE LIMITS FOR THE TRUE DIFFERENCE DUE TO EACH EXPERIMENTAL FACTOR (Continued)

SAS

COMPOUND=Extractable Organic Mass (mg/m^3)

PARAMETER	1984 LCL	1984 ESTIMATE	1984 UCL	1987 LCL	1987 ESTIMATE	1987 UCL
CIGARETTES	-0.020	0.060	0.140	0.050	0.130	0.210
COOKING	-0.100	0.020	0.140	-0.206	-0.086	0.034
HEATING	-0.168	-0.008	0.152	0.012	0.184	0.316
LOCATION	-0.076	-0.028	0.020	-0.052	0.000	0.052

APPENDIX C

Comparison of 1984 and 1987 Prediction Equations For Estimating Levels of PAH Target Compounds From Measured Levels of Potential PAH Marker Compounds

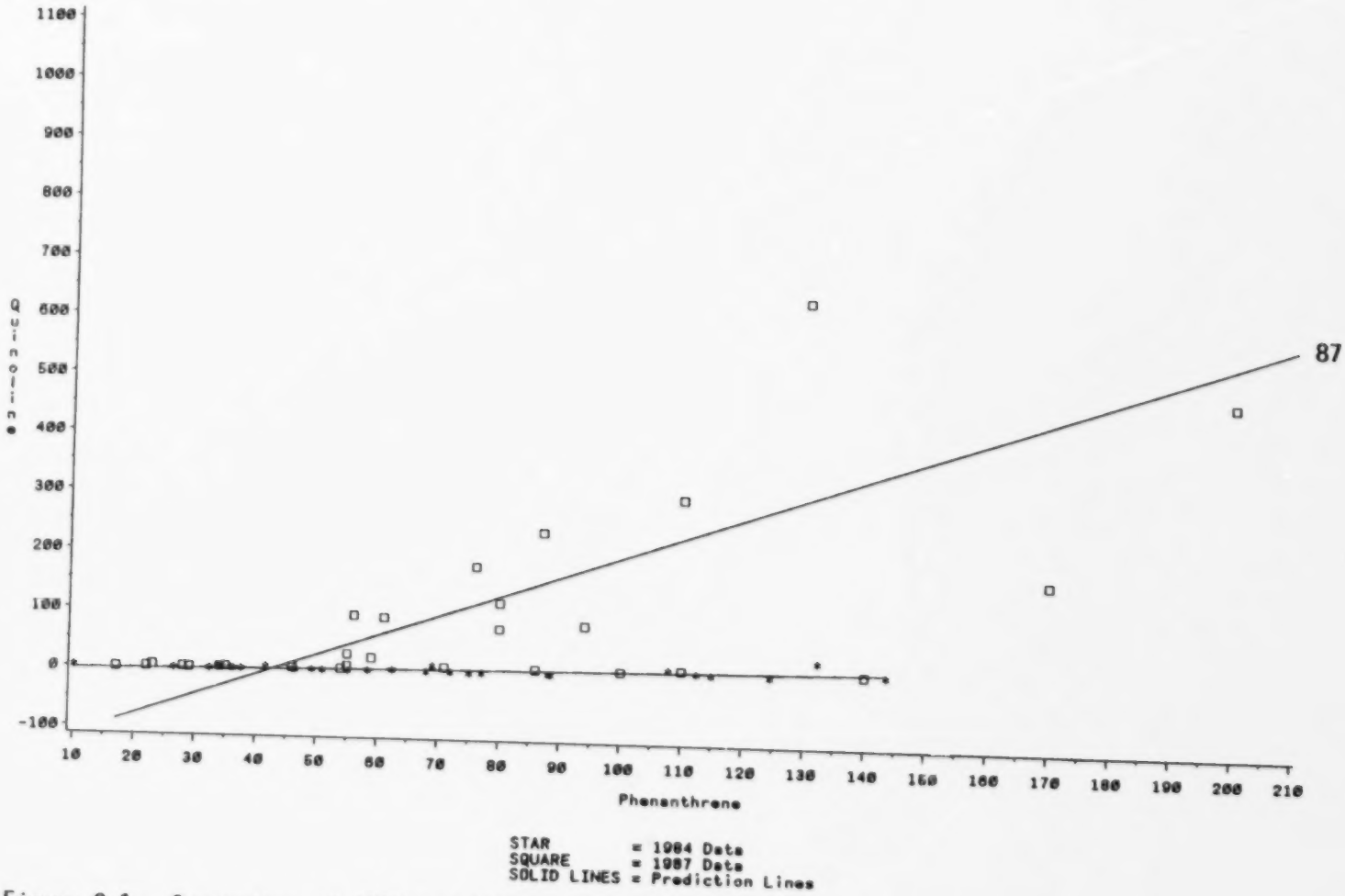


Figure C-1. Comparison of 1984 and 1987 Study Data for Predicting Quinoline Concentration Levels from Measured Levels of Phenanthrene (ng/m^3).

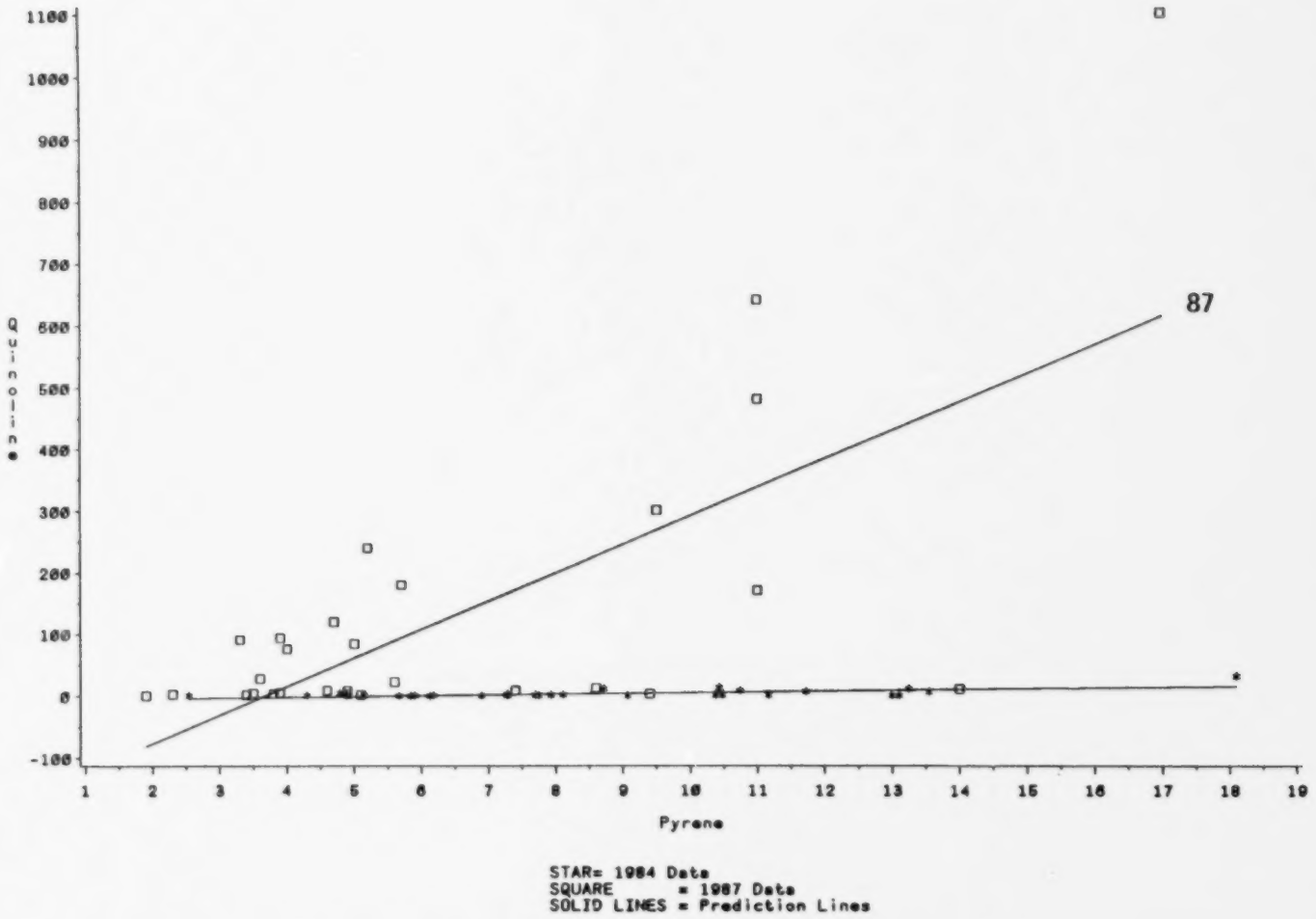


Figure C-2. Comparison of 1984 and 1987 Study Data for Predicting Quinoline Concentration Levels from Measured Levels of Pyrene (ng/m^3).

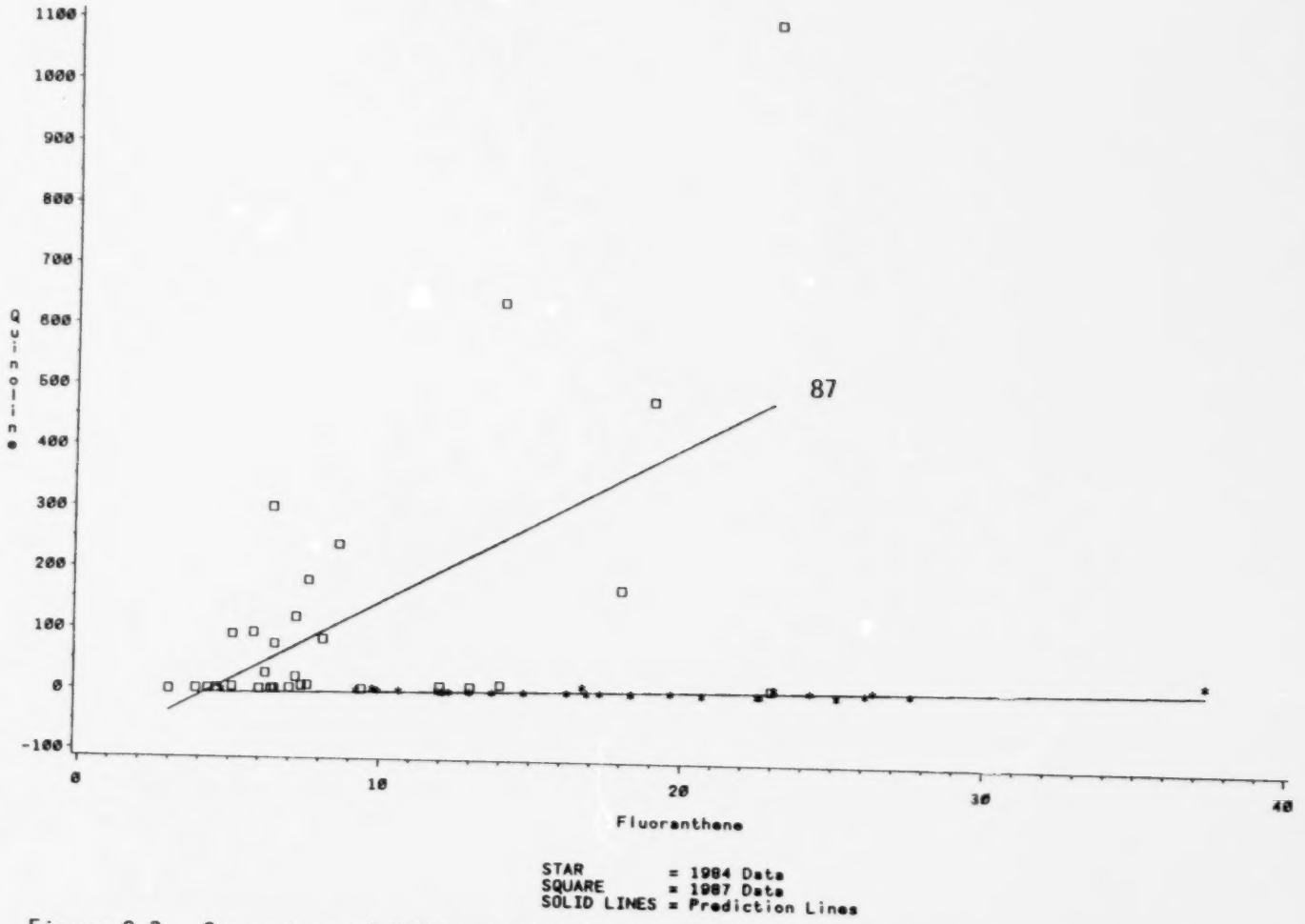


Figure C-3. Comparison of 1984 and 1987 Study Data for Predicting Quinoline Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

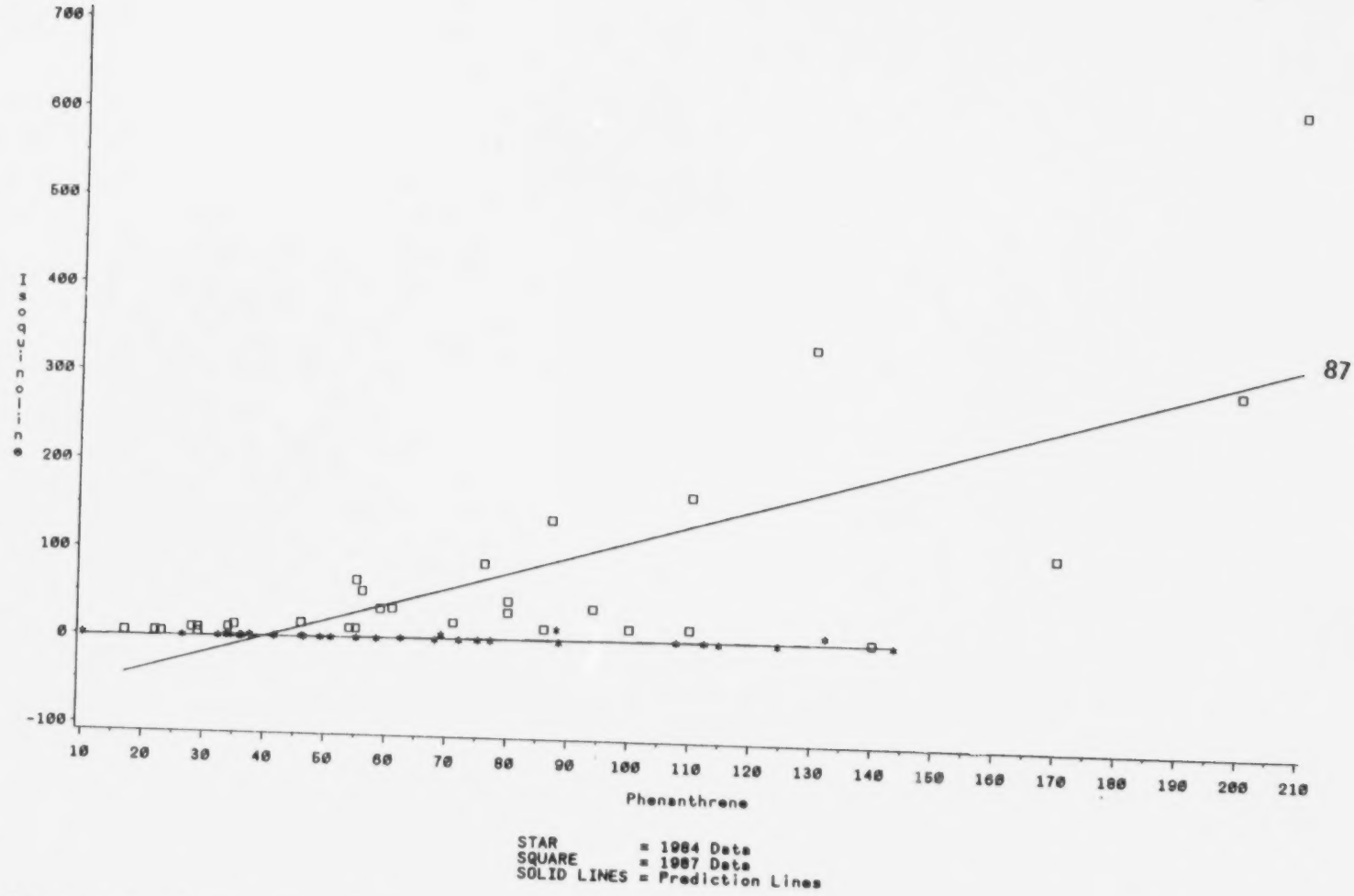


Figure C-4. Comparison of 1984 and 1987 Study Data for Predicting Isoquinoline Concentration Levels from Measured Levels of Phenanthrene (ng/m3)

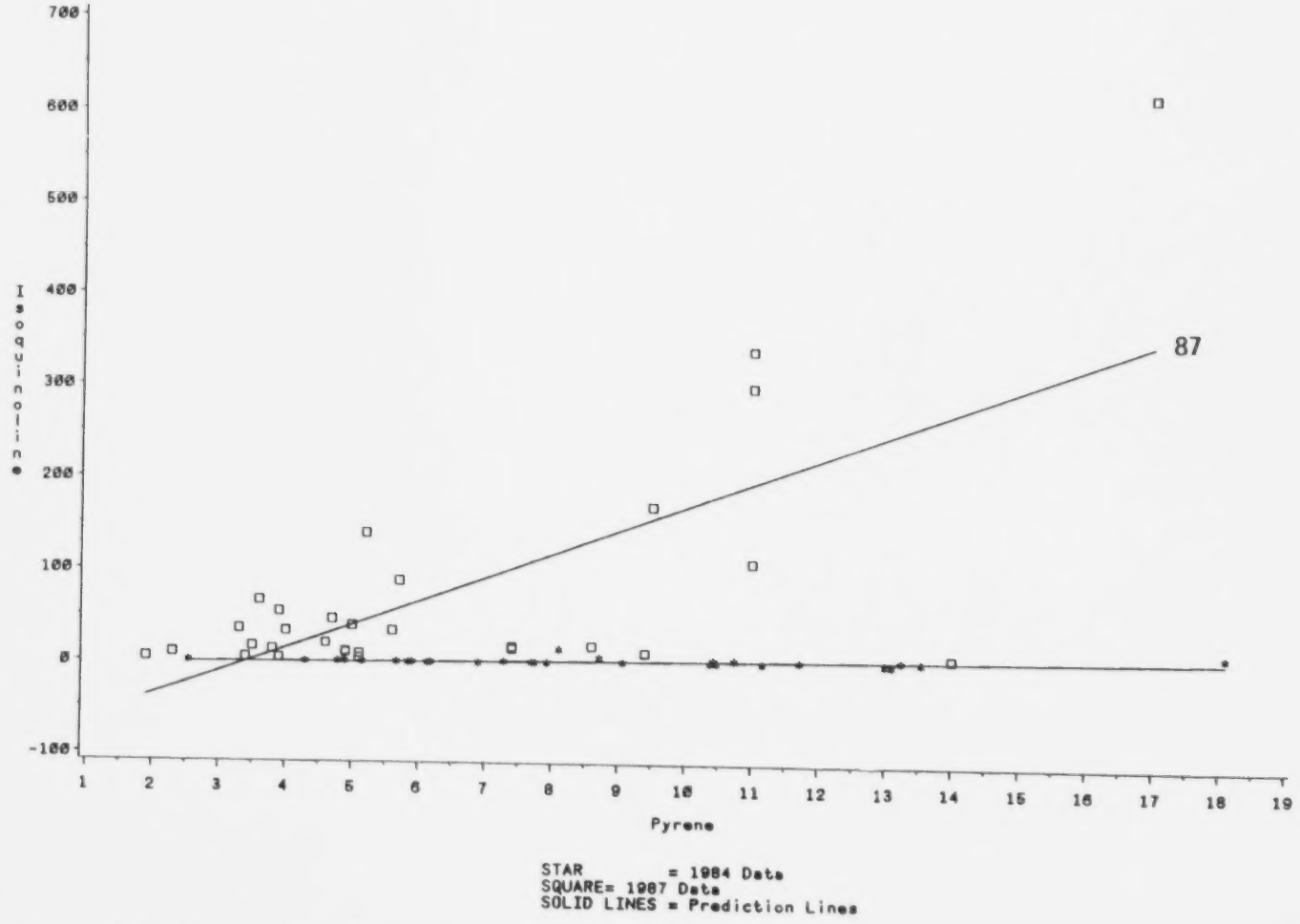


Figure C-5. Comparison of 1984 and 1987 Study Data for Predicting Isoquinoline Concentration Levels from Measured Levels of Pyrene (ng/m^3).

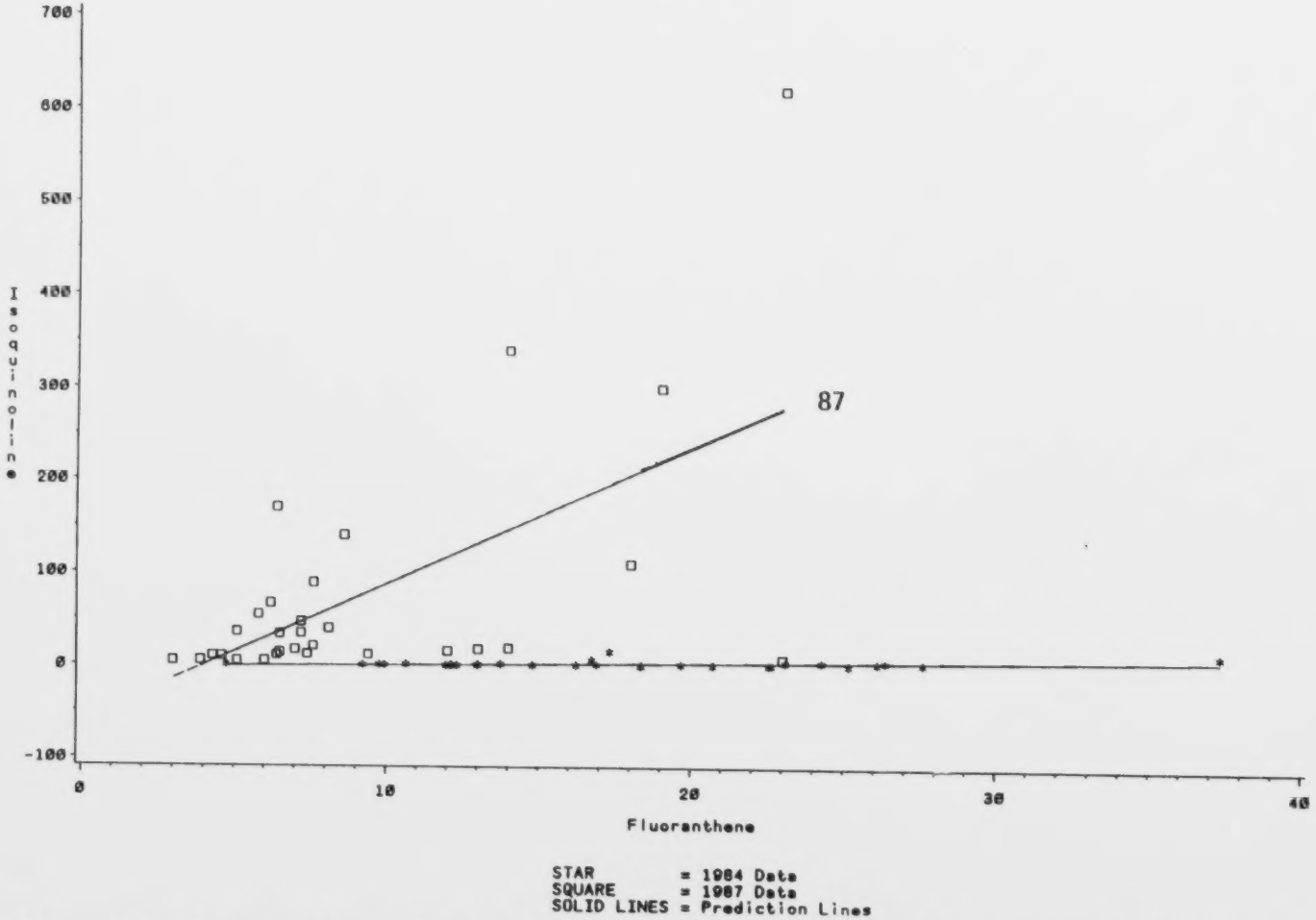


Figure C-6. Comparison of 1984 and 1987 Study Data for Predicting Isoquinoline Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

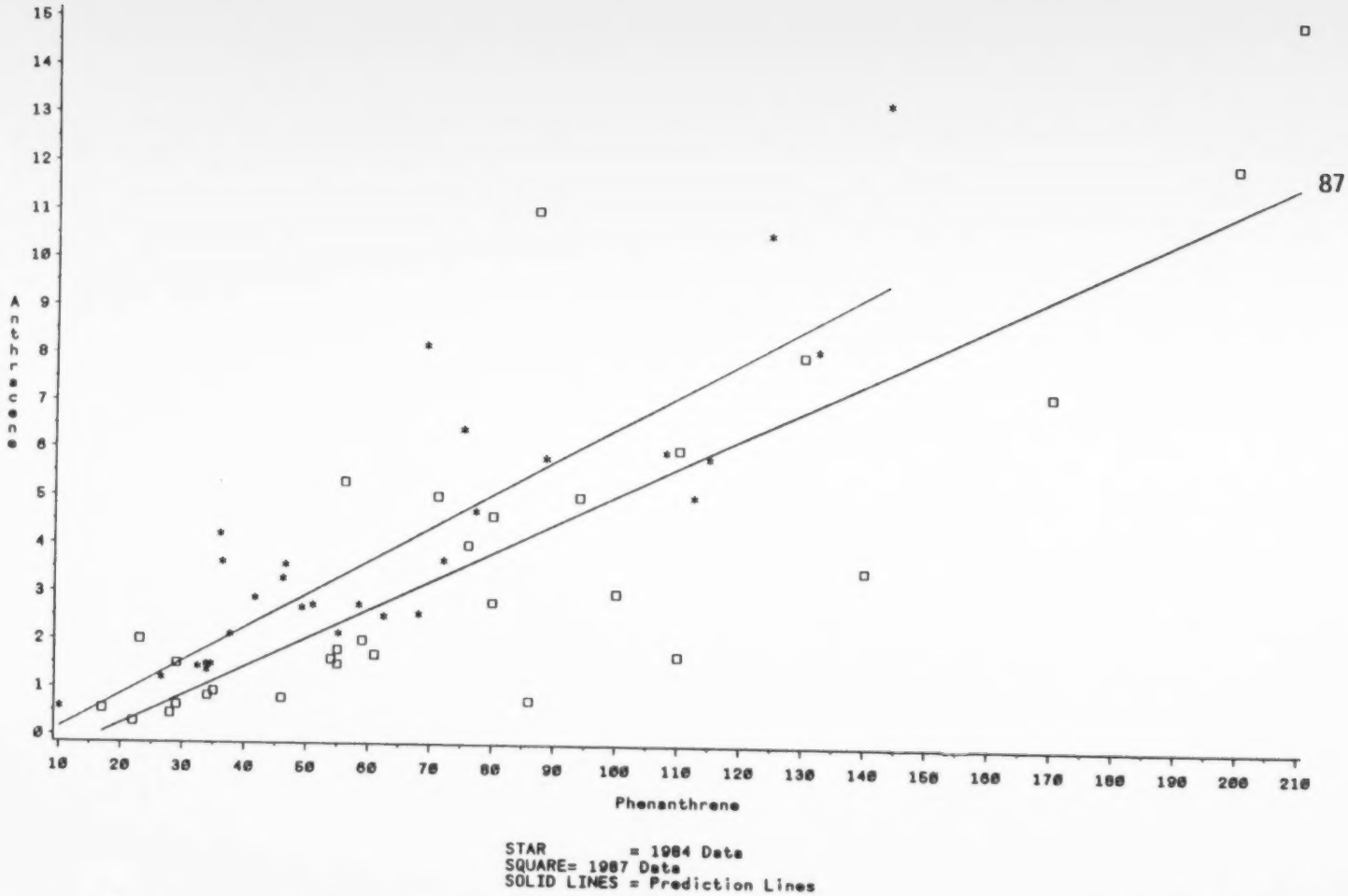


Figure C-7. Comparison of 1984 and 1987 Study Data for Predicting Anthracene Concentration Levels from Measured Levels of Phenanthrene (ng/m^3).

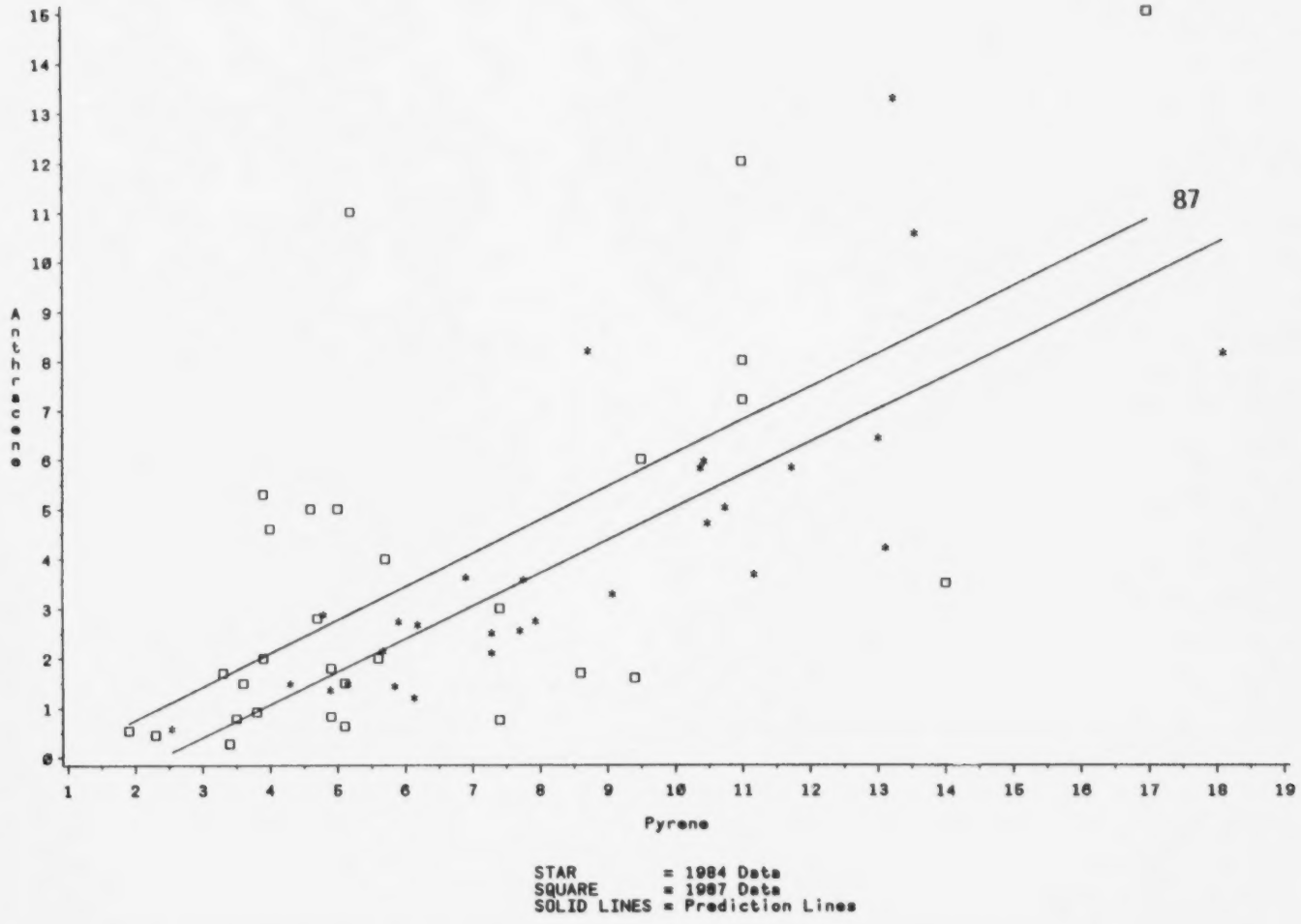


Figure C-8. Comparison of 1984 and 1987 Study Data for Predicting Anthracene Concentration Levels from Measured Levels of Pyrene (ng/m^3).

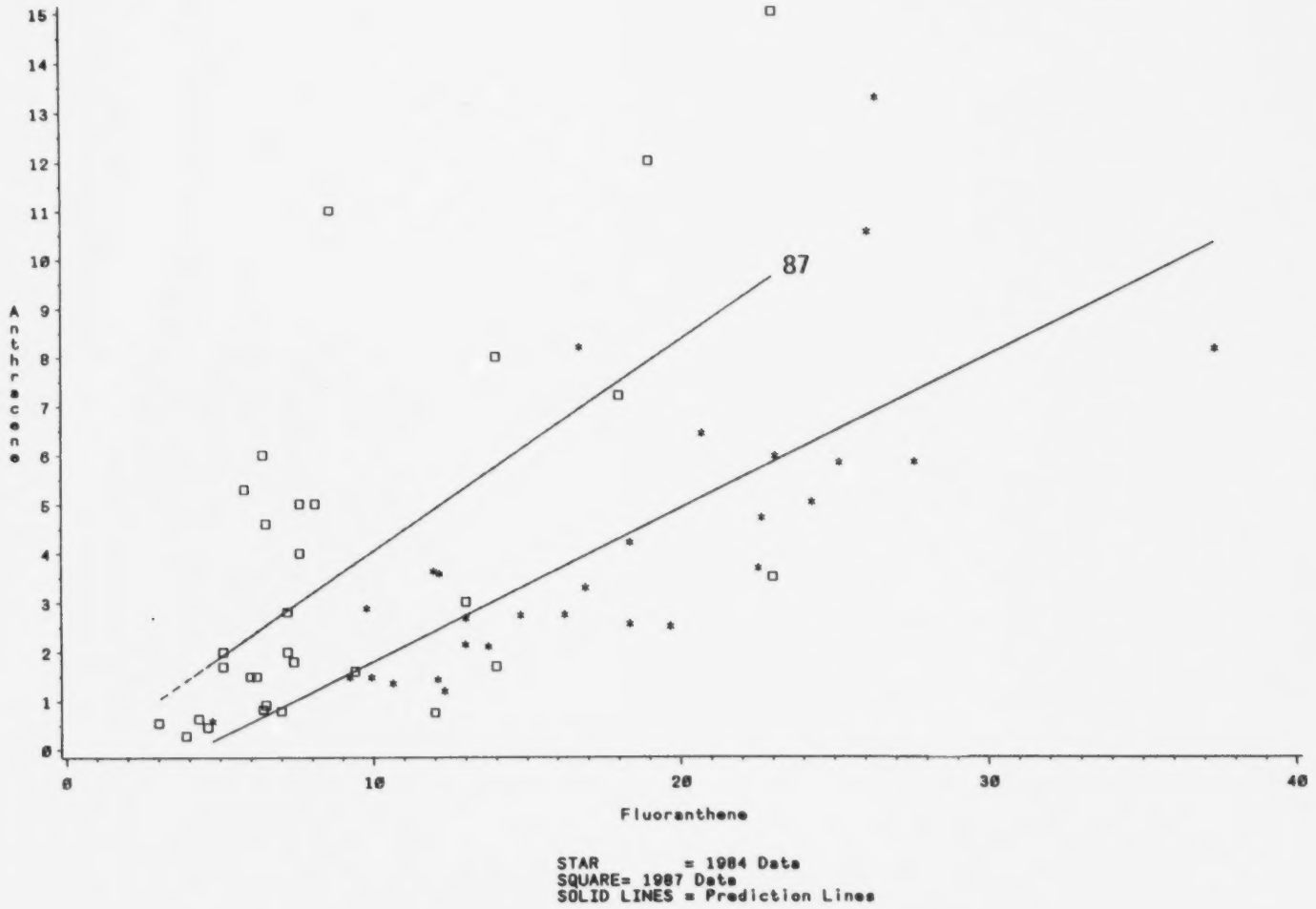


Figure C-9. Comparison of 1984 and 1987 Study Data for Predicting Anthracene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).

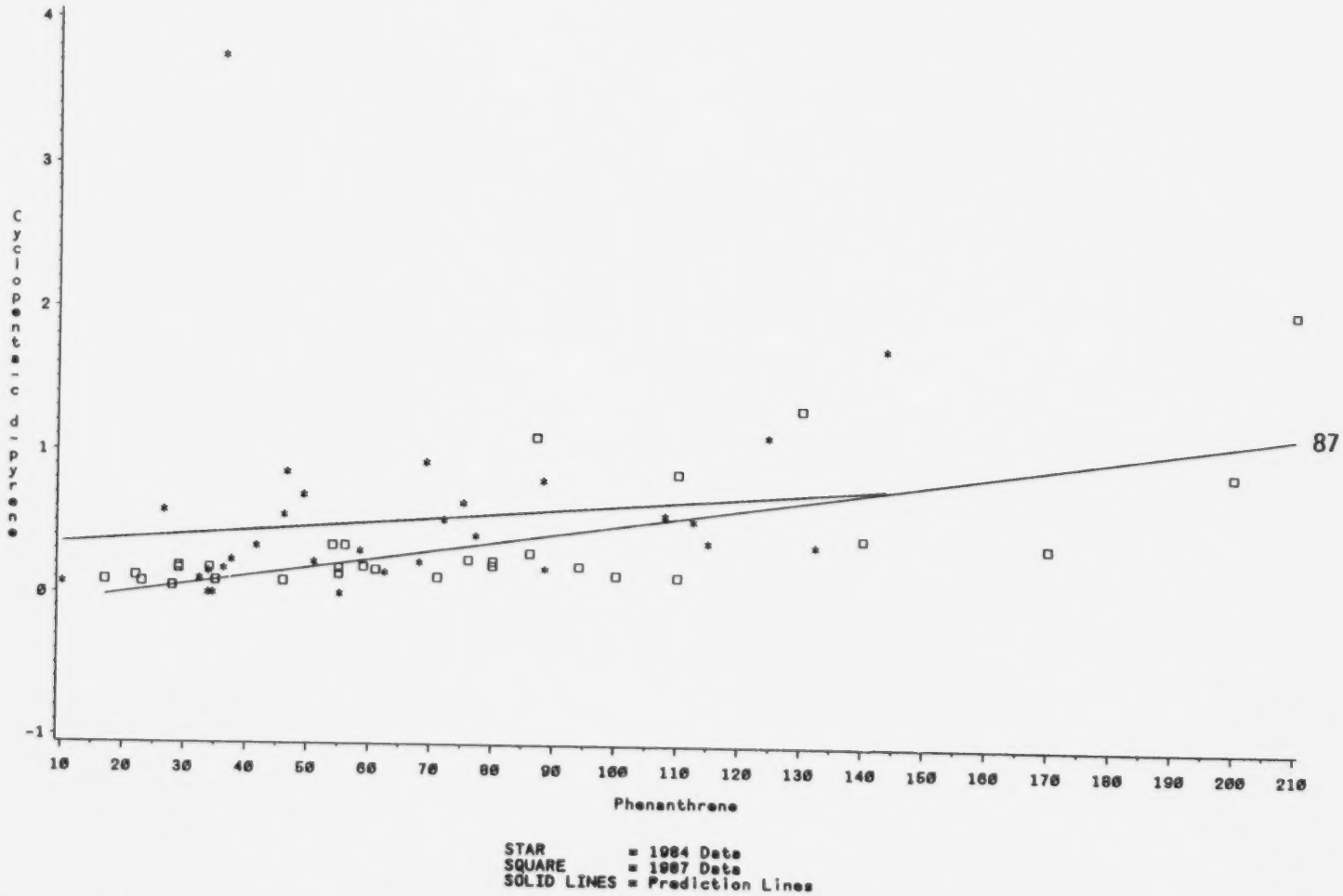


Figure C-10. Comparison of 1984 and 1987 Study Data for Predicting Cyclopenta(c,d)pyrene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

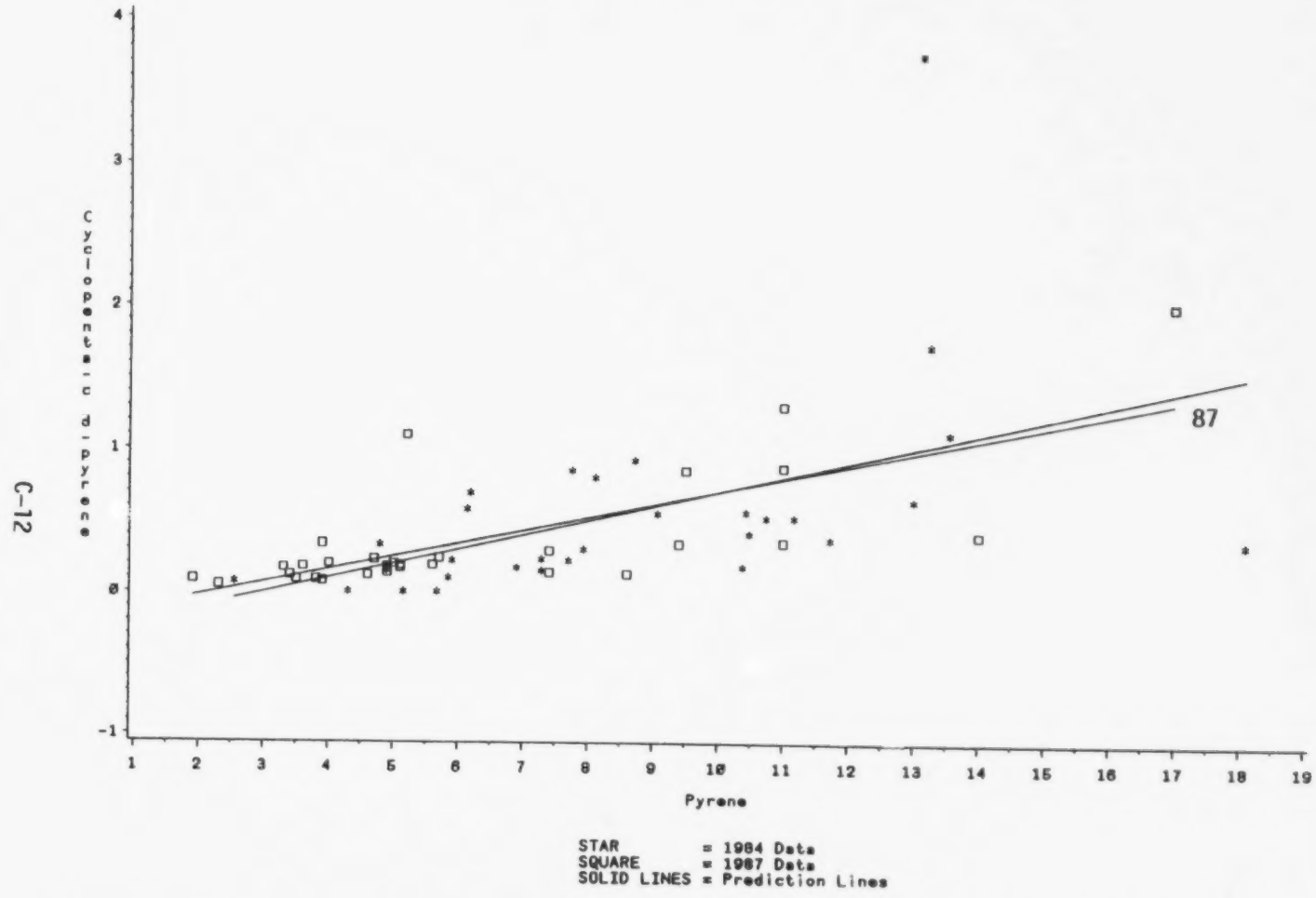


Figure C-11. Comparison of 1984 and 1987 Study Data for Predicting Cyclopenta(c,d)pyrene Concentration Levels from Measured Levels of Pyrene (ng/m3).

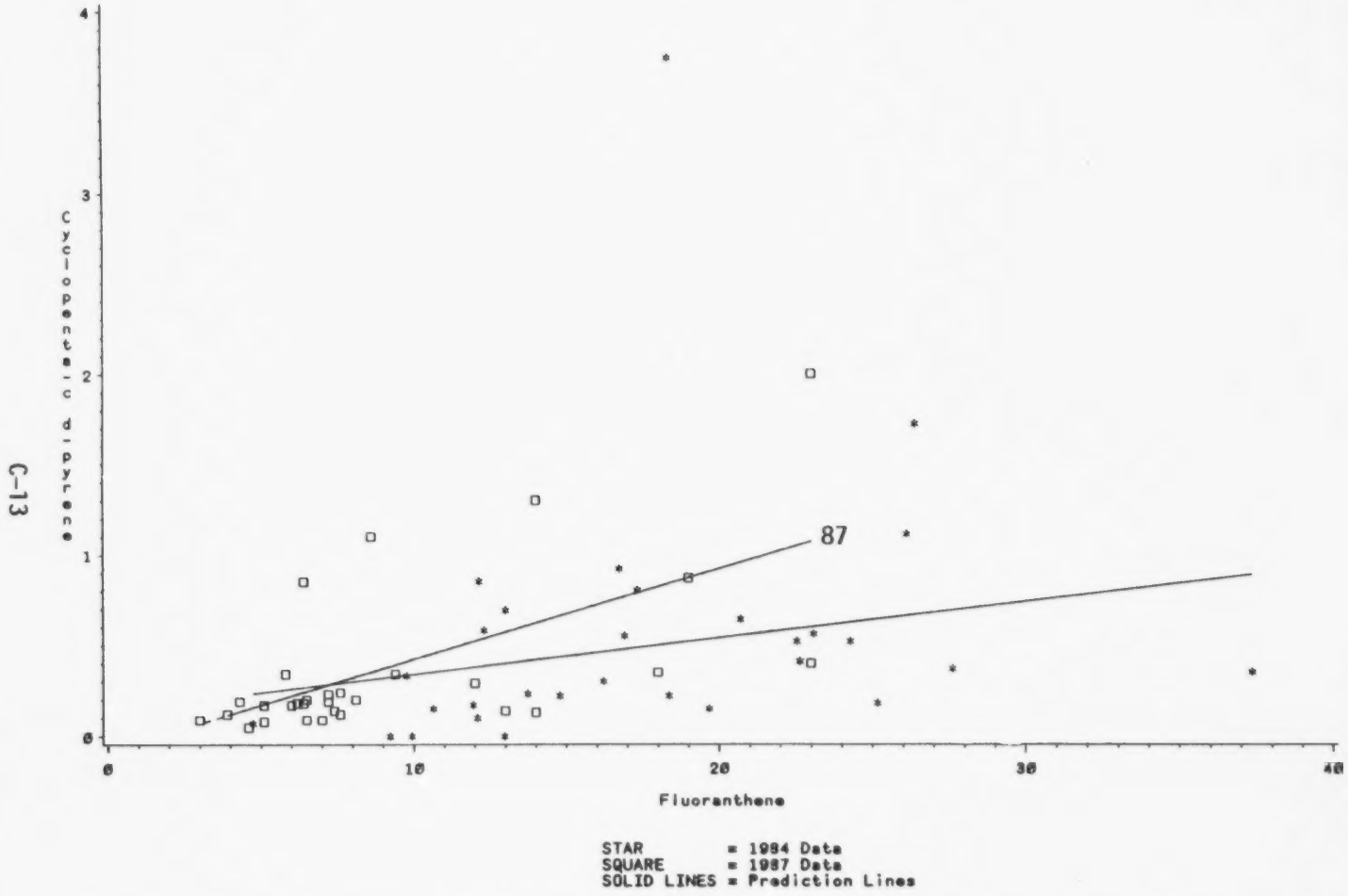


Figure C-12. Comparison of 1984 and 1987 Study Data for Predicting Cyclopenta(c,d)pyrene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

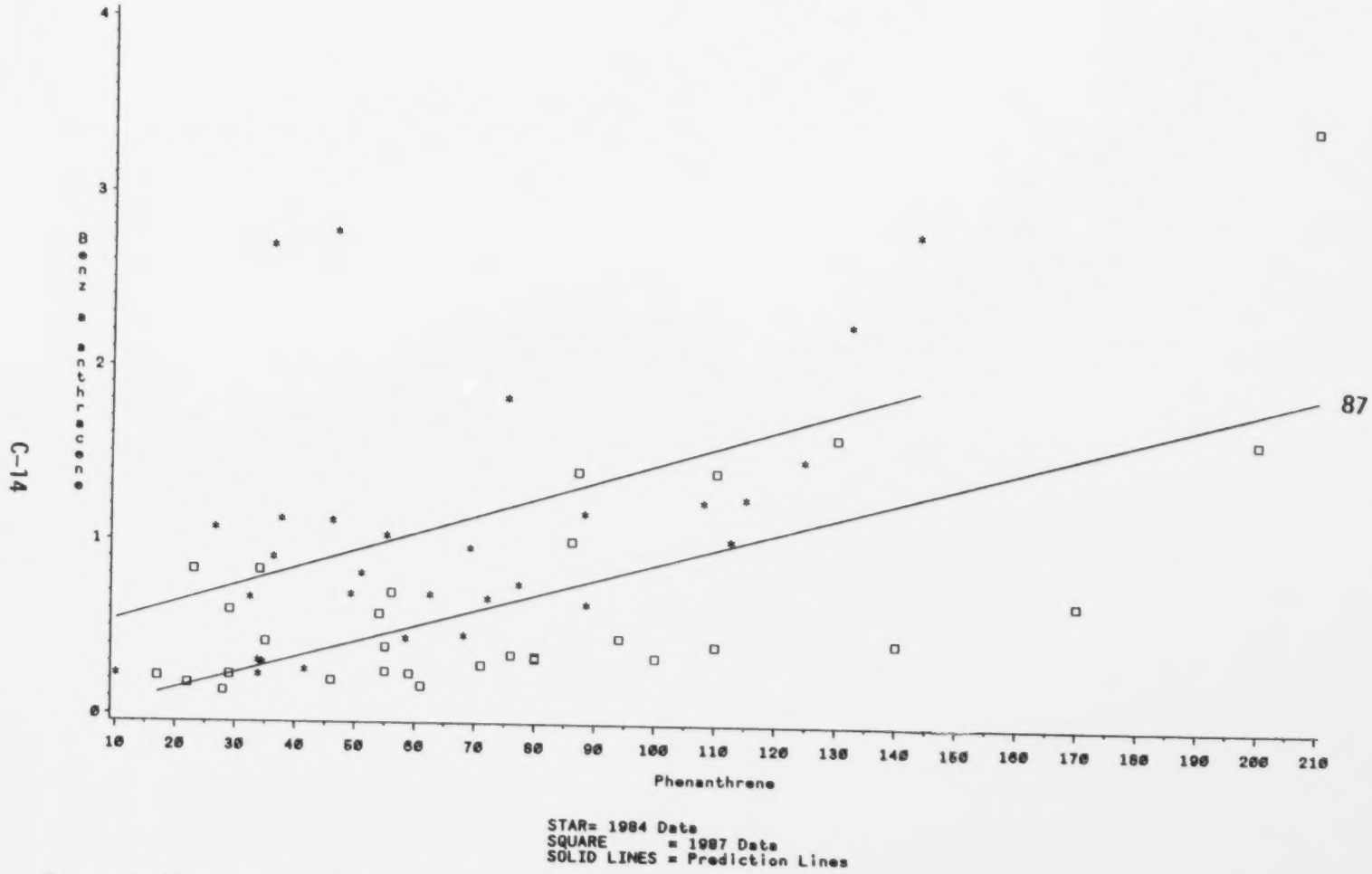


Figure C-13. Comparison of 1984 and 1987 Study Data for Predicting Benz(a)anthracene Concentration Levels from Measured Levels of Phenanthrene (ng/m^3).

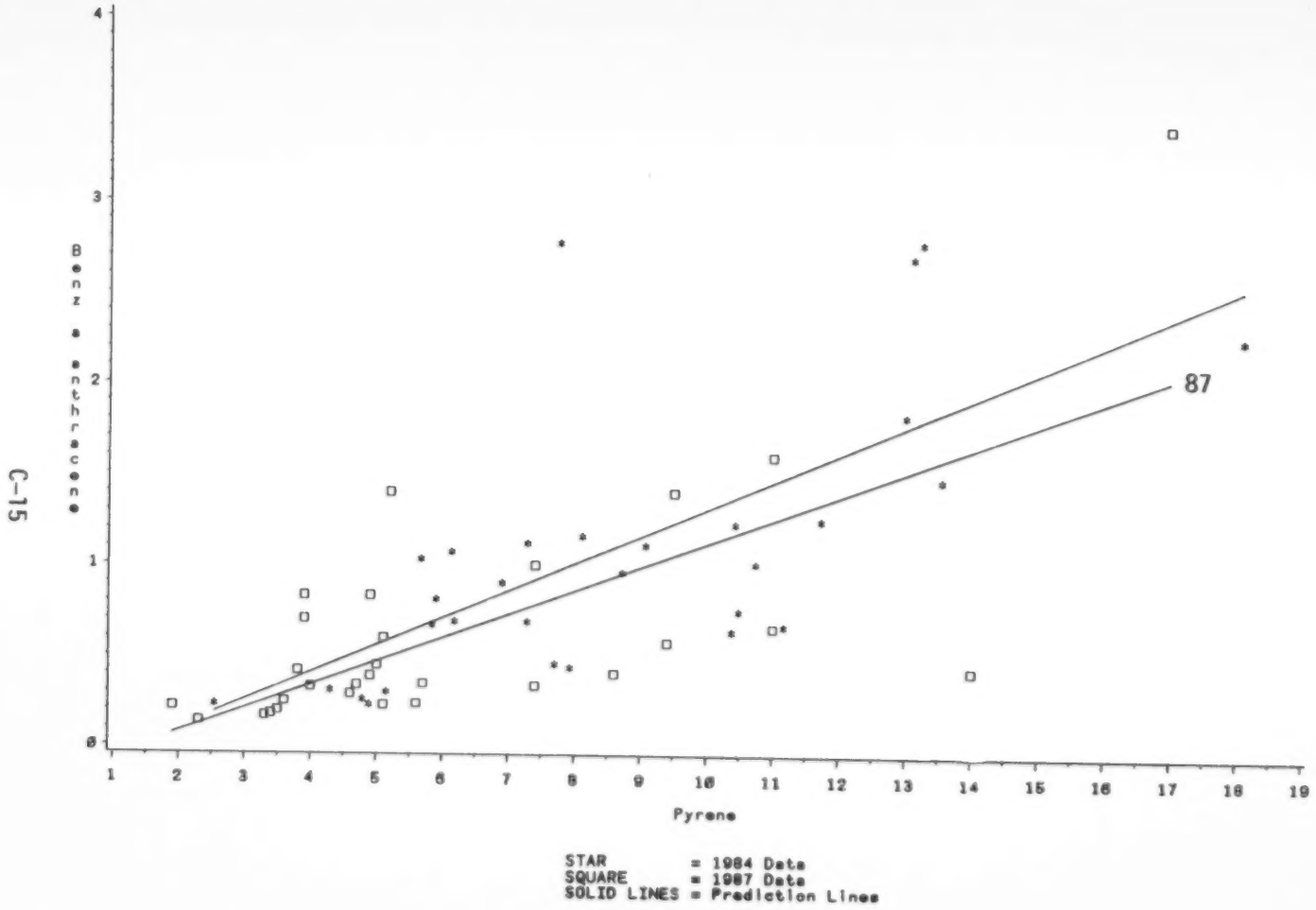


Figure C-14. Comparison of 1984 and 1987 Study Data for Predicting Benz(a)anthracene Concentration Levels from Measured Levels of Pyrene (ng/m^3).

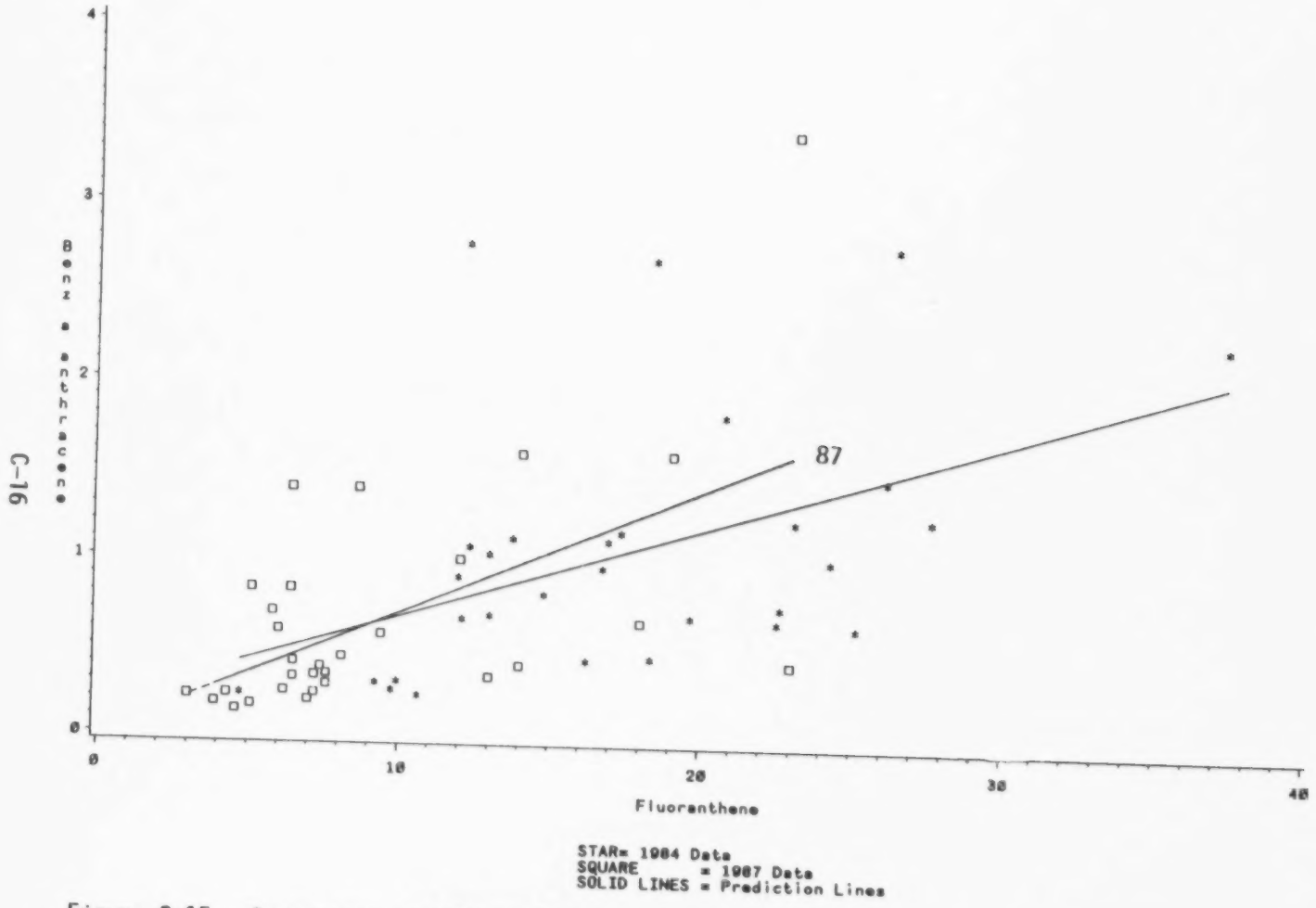


Figure C-15. Comparison of 1984 and 1987 Study Data for Predicting Benz(a)anthracene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).

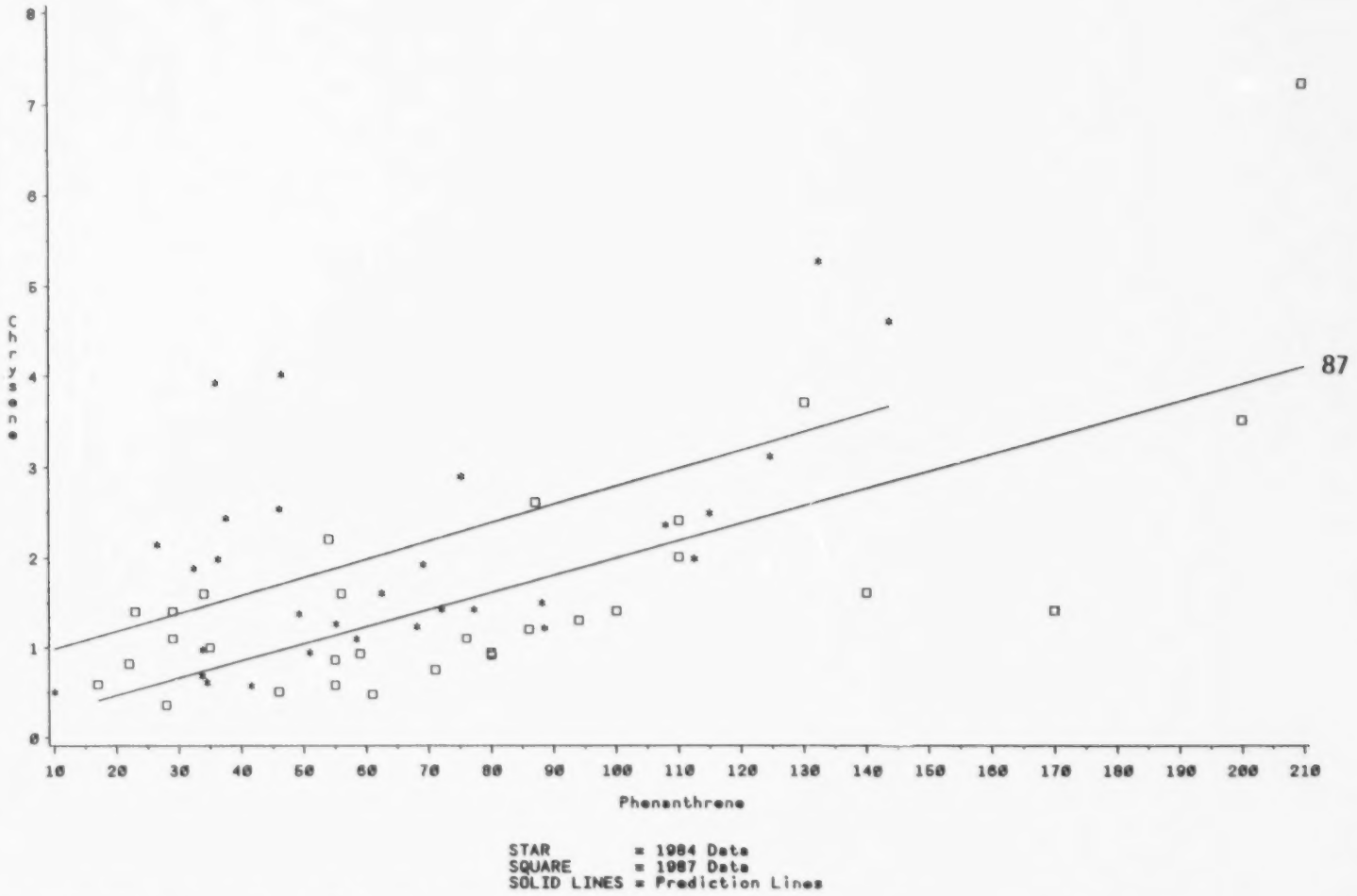


Figure C-16. Comparison of 1984 and 1987 Study Data for Predicting Chrysene Concentration Levels from Measured Levels of Phenanthrene (ng/m^3).

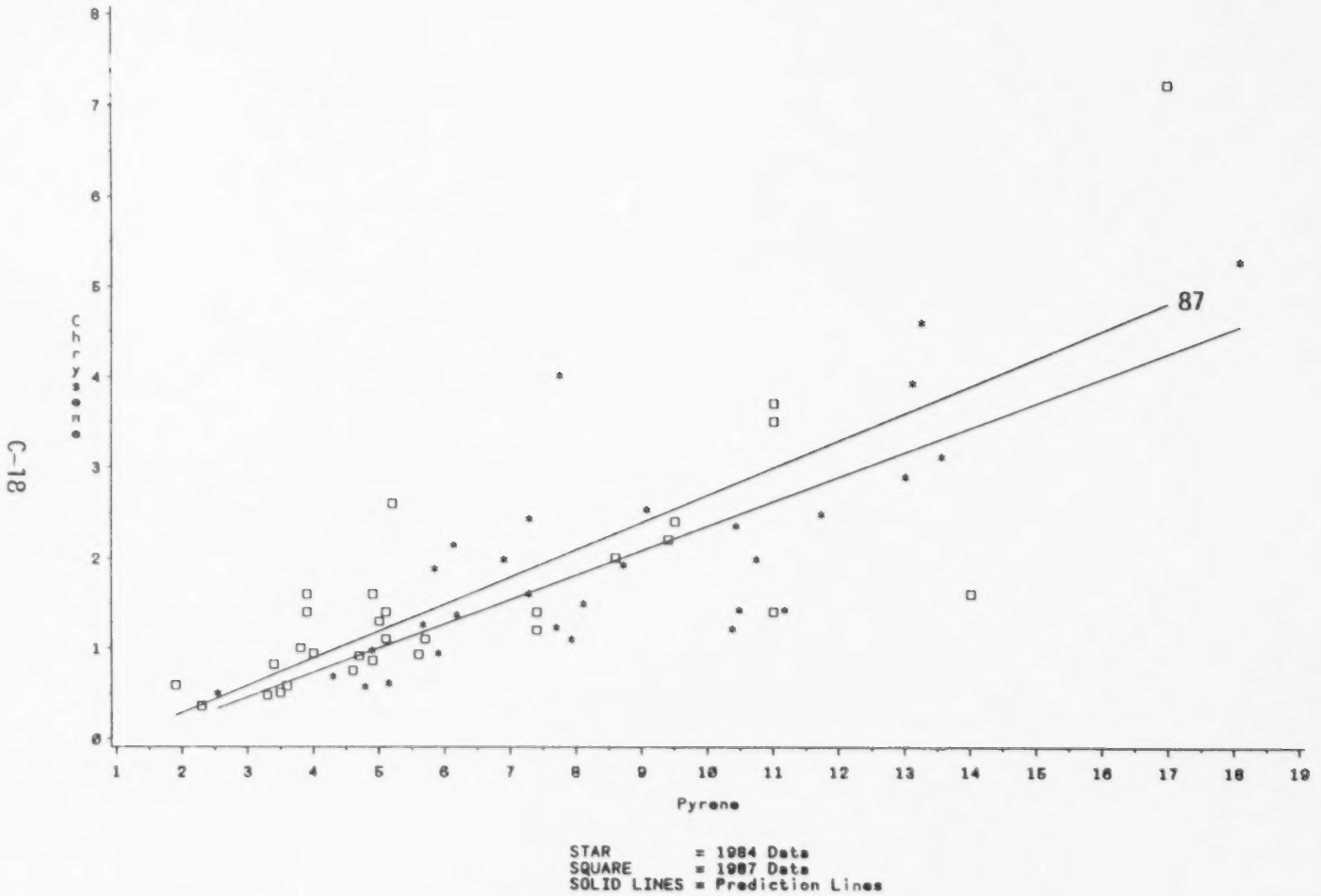


Figure C-17. Comparison of 1984 and 1987 Study Data for Predicting Chrysene Concentration Levels from Measured Levels of Pyrene (ng/m3).

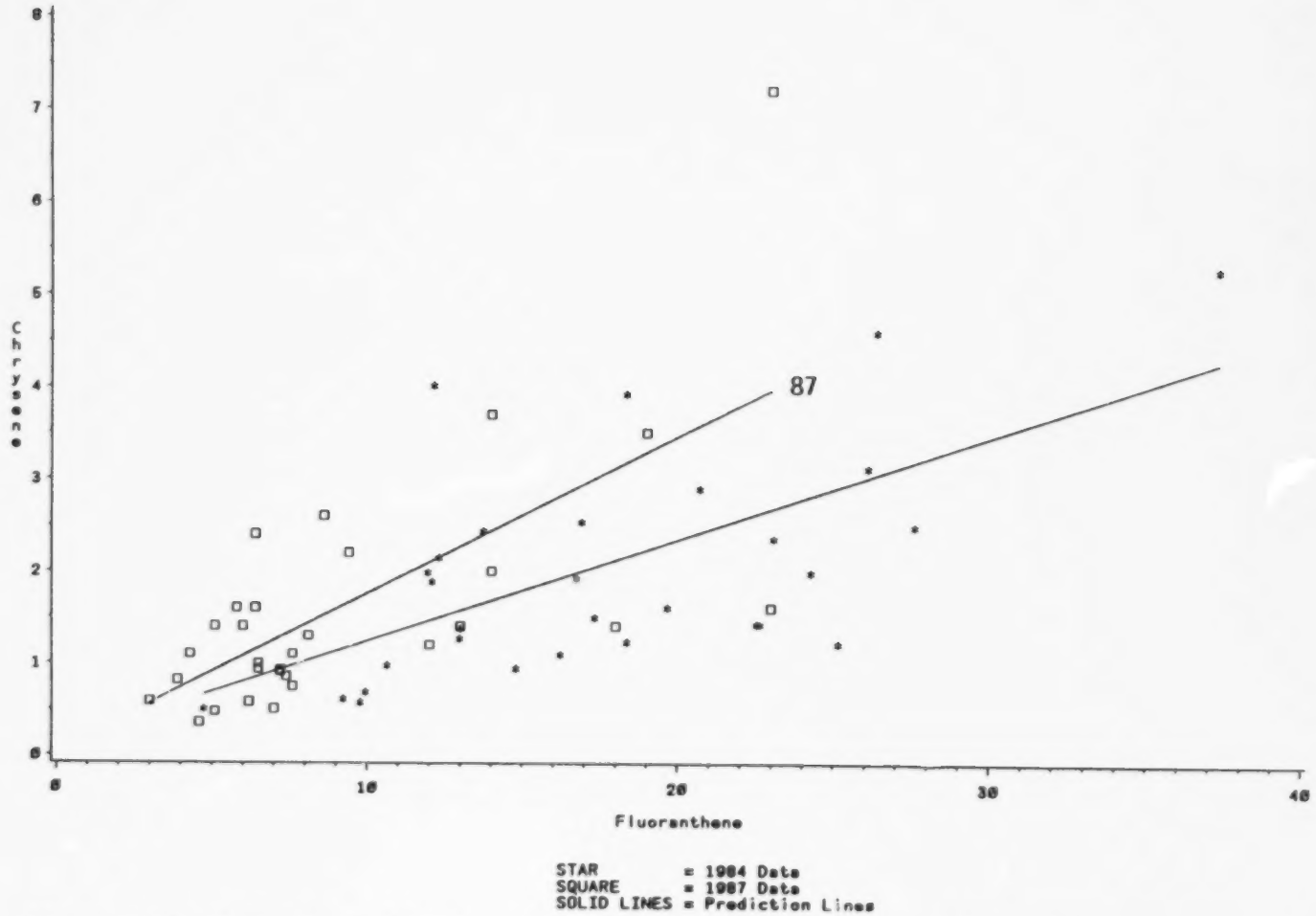
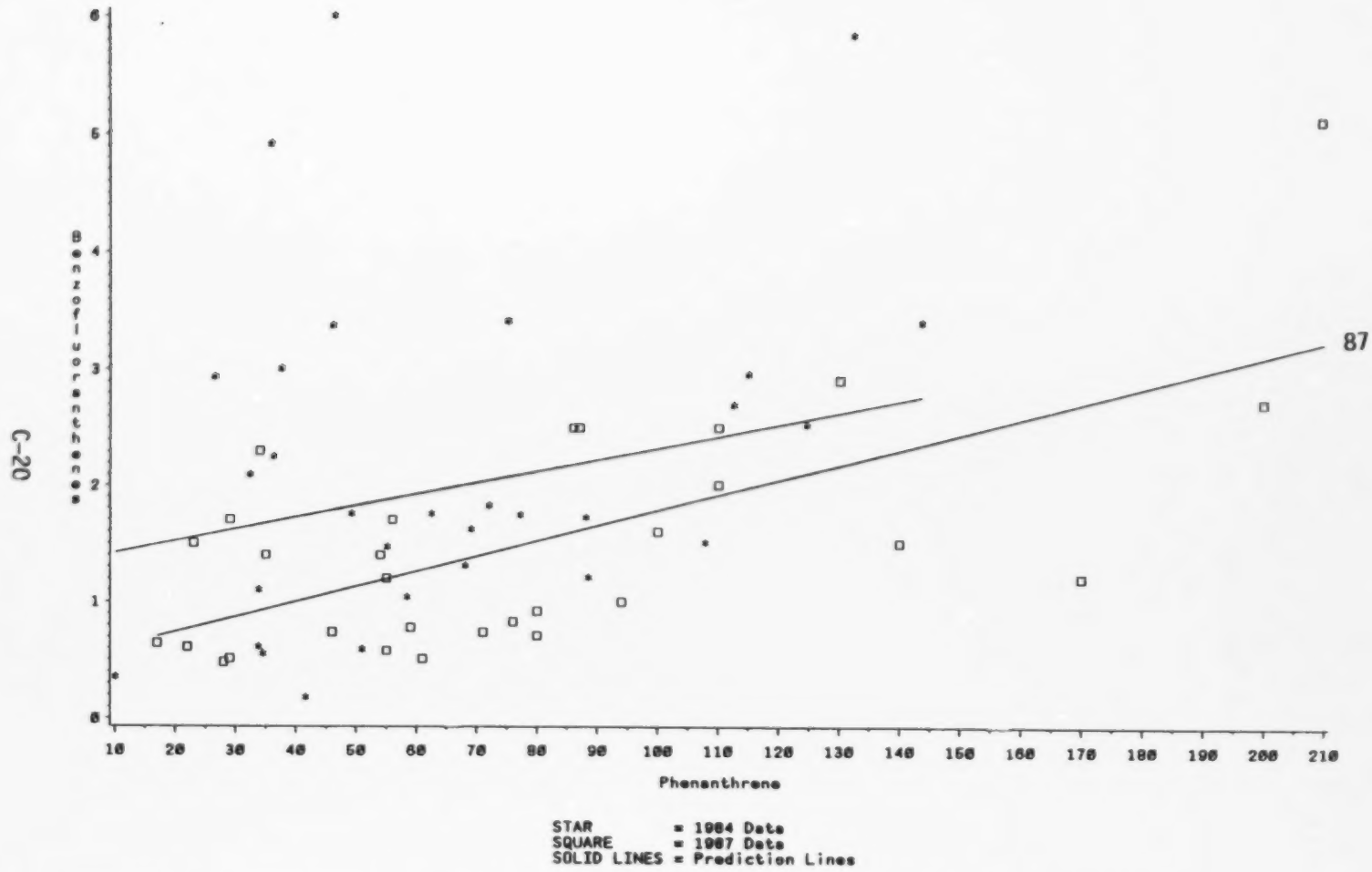


Figure C-18. Comparison of 1984 and 1987 Study Data for Predicting Chrysene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).



C-20

Figure C-19. Comparison of 1984 and 1987 Study Data for Predicting Benzofluoranthenes Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

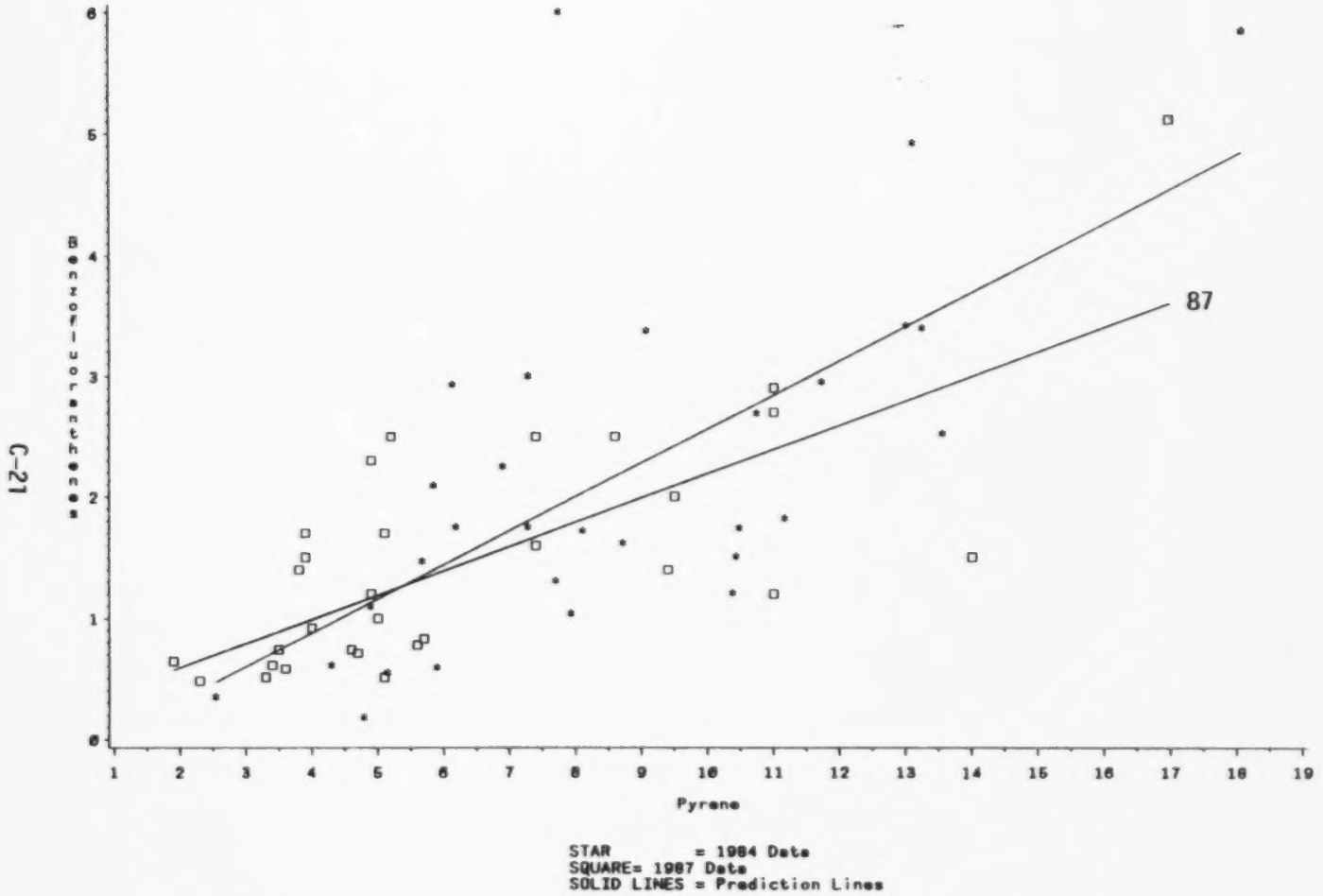


Figure C-20. Comparison of 1984 and 1987 Study Data for Predicting Benzofluoranthenes Concentration Levels from Measured Levels of Pyrene (ng/m^3).

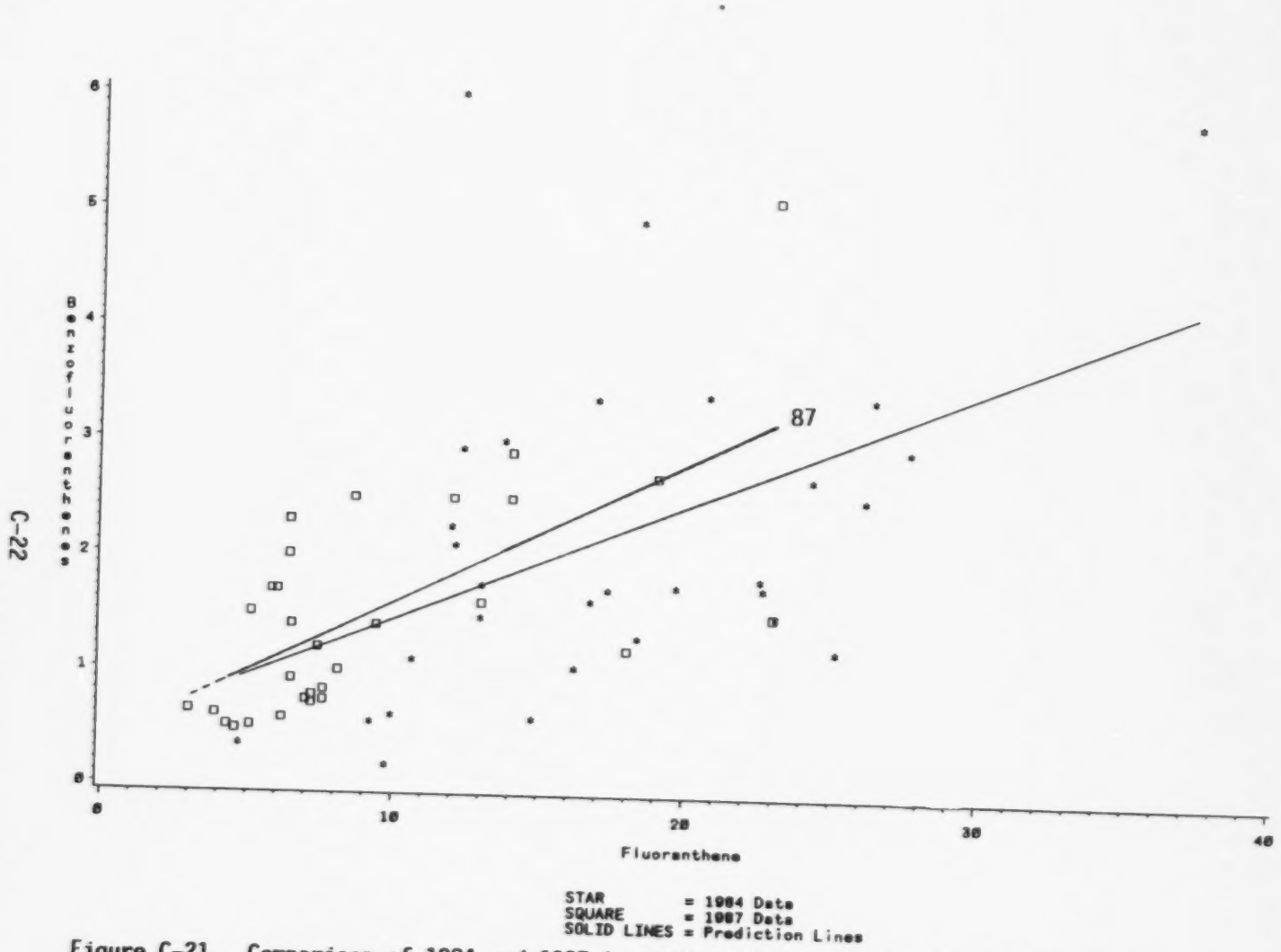


Figure C-21. Comparison of 1984 and 1987 Study Data for Predicting Benzofluoranthenes Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

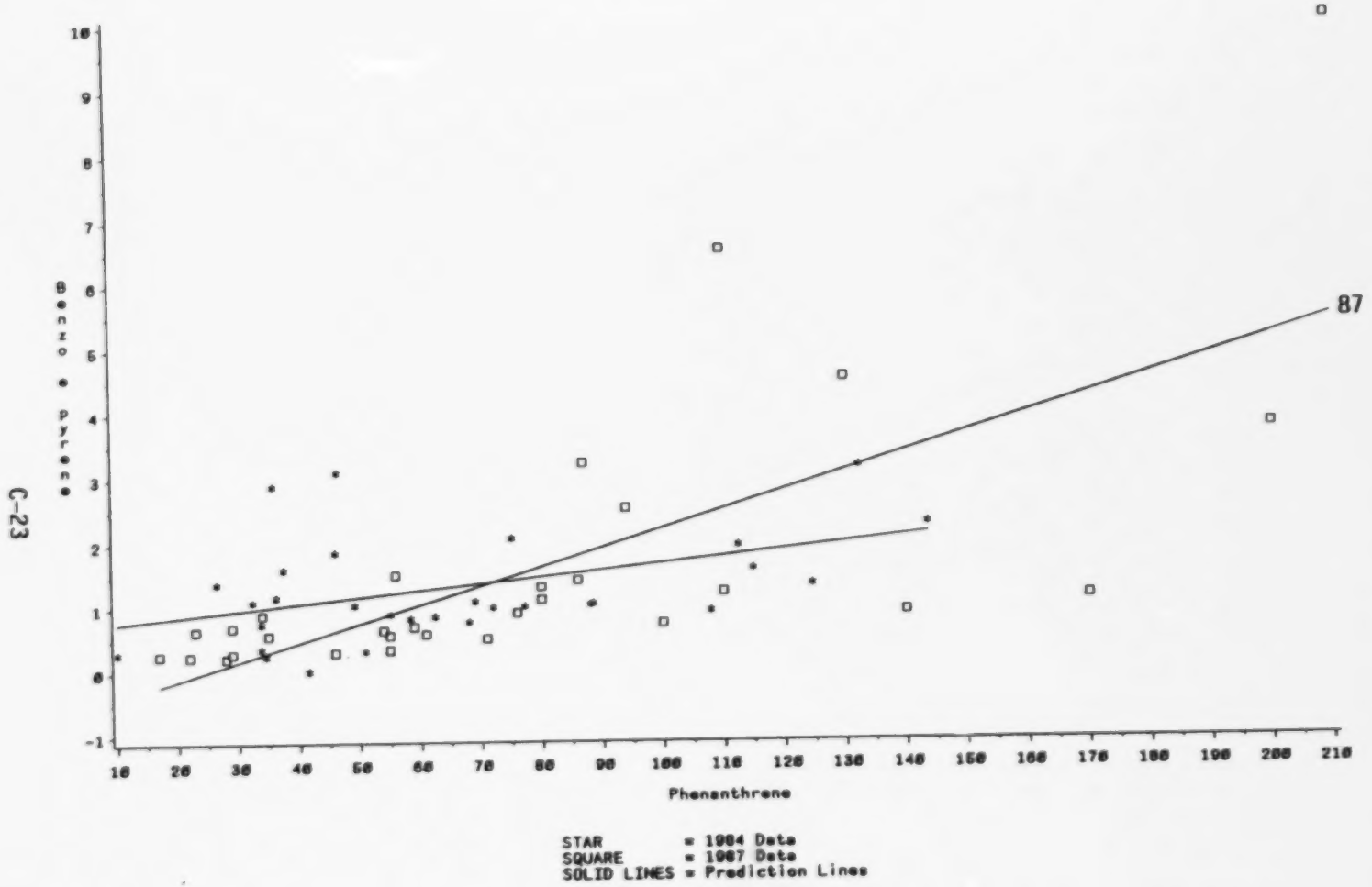


Figure C-22. Comparison of 1984 and 1987 Study Data for Predicting Benzo(e)pyrene Concentration Levels from Measured Levels of Phenanthrene (ng/m^3).

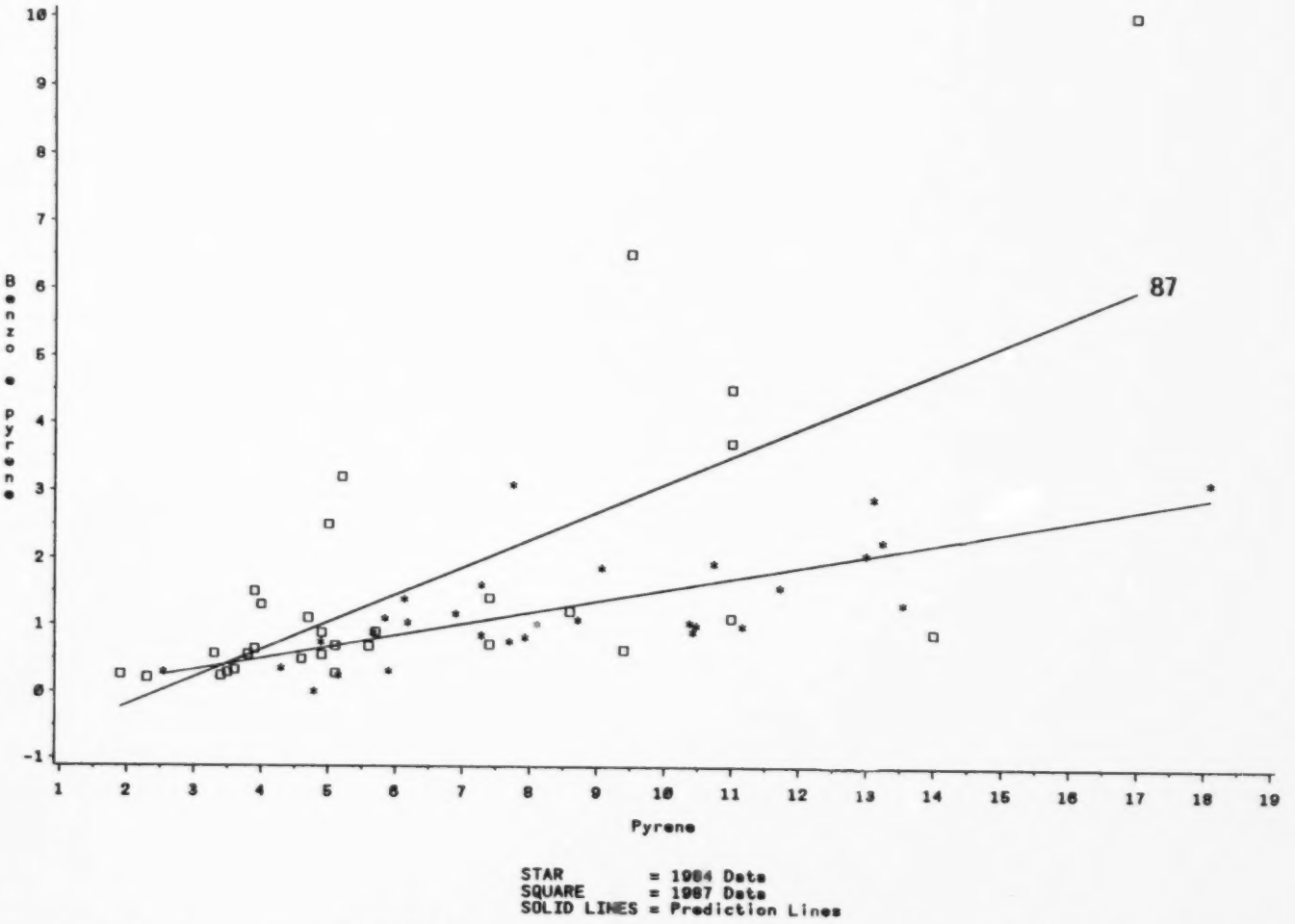


Figure C-23. Comparison of 1984 and 1987 Study Data for Predicting Benzo(e)pyrene Concentration Levels from Measured Levels of Pyrene (ng/m^3).

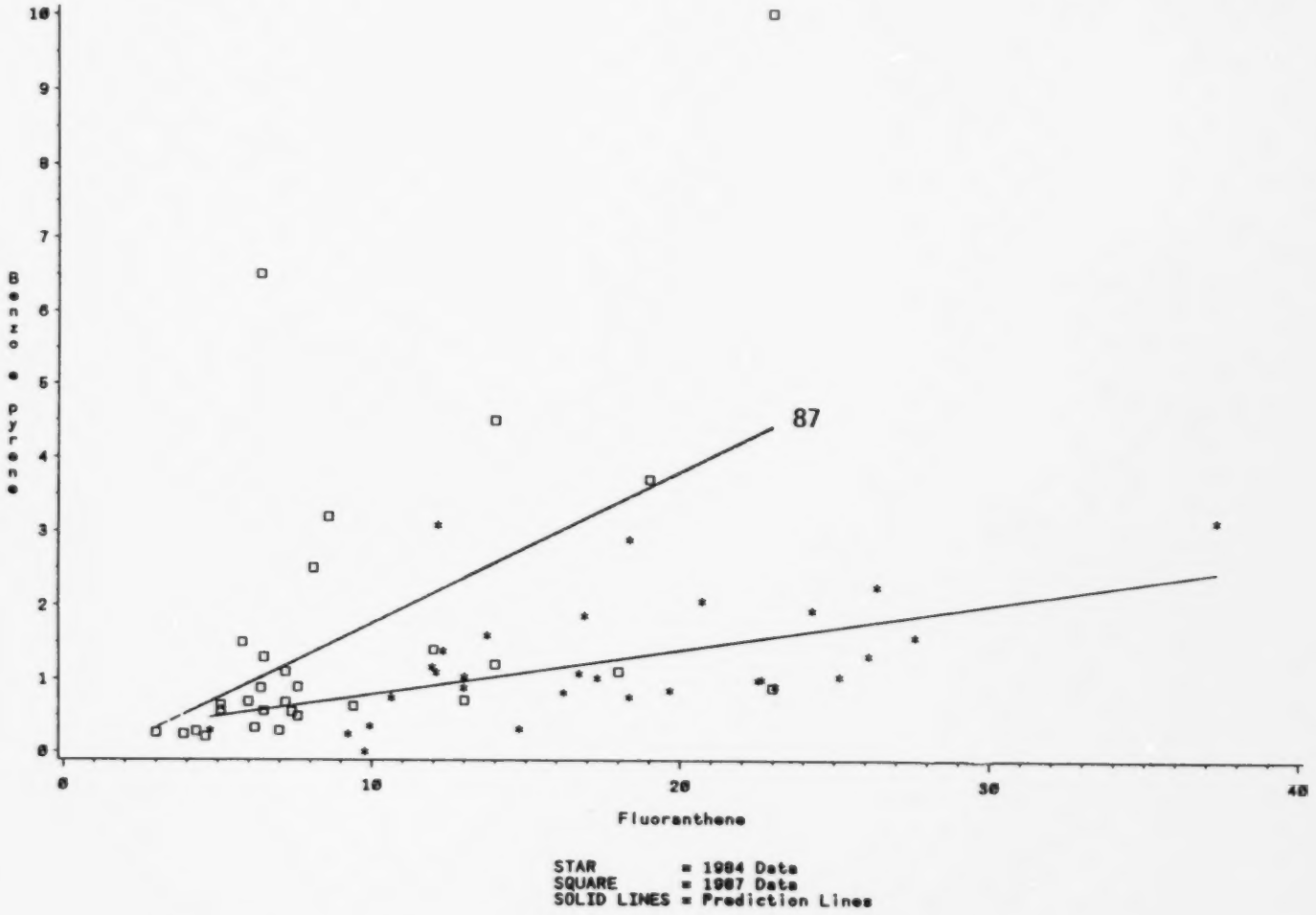


Figure C-24. Comparison of 1984 and 1987 Study Data for Predicting Benzo(e)pyrene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

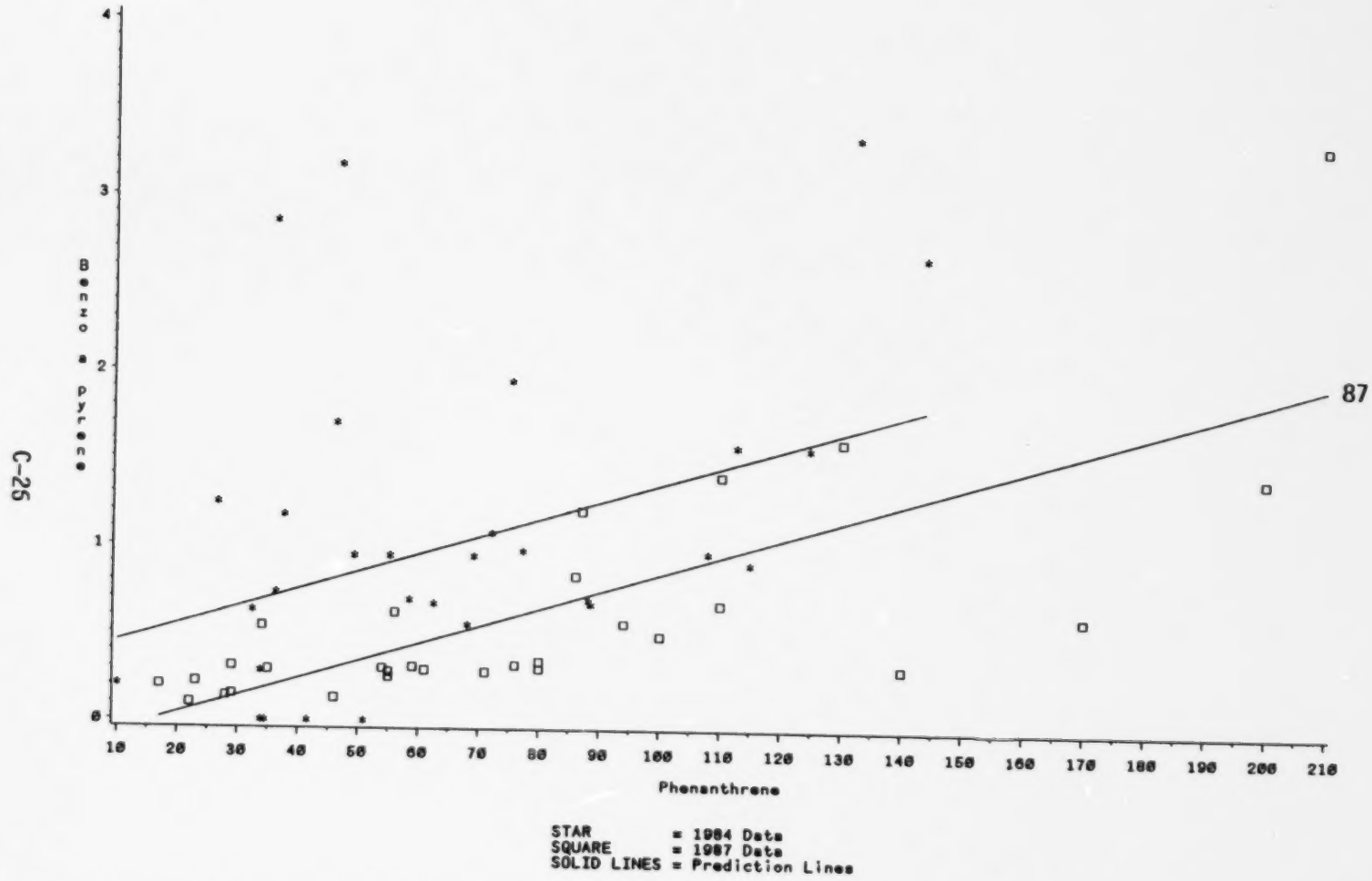


Figure C-25. Comparison of 1984 and 1987 Study Data for Predicting Benzo(a)pyrene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

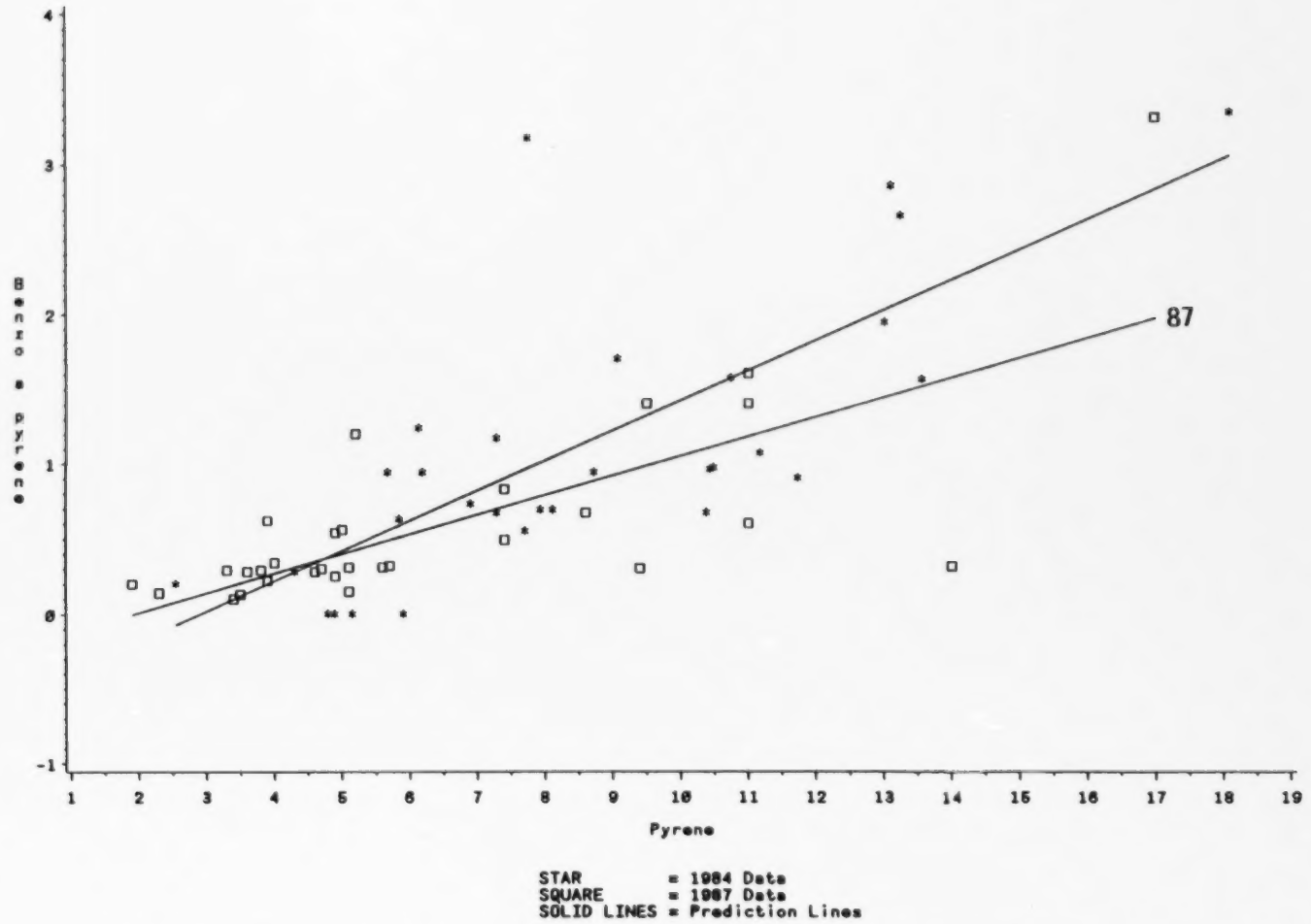


Figure C-26. Comparison of 1984 and 1987 Study Data for Predicting Benzo(a)pyrene Concentration Levels from Measured Levels of Pyrene (ng/m3).

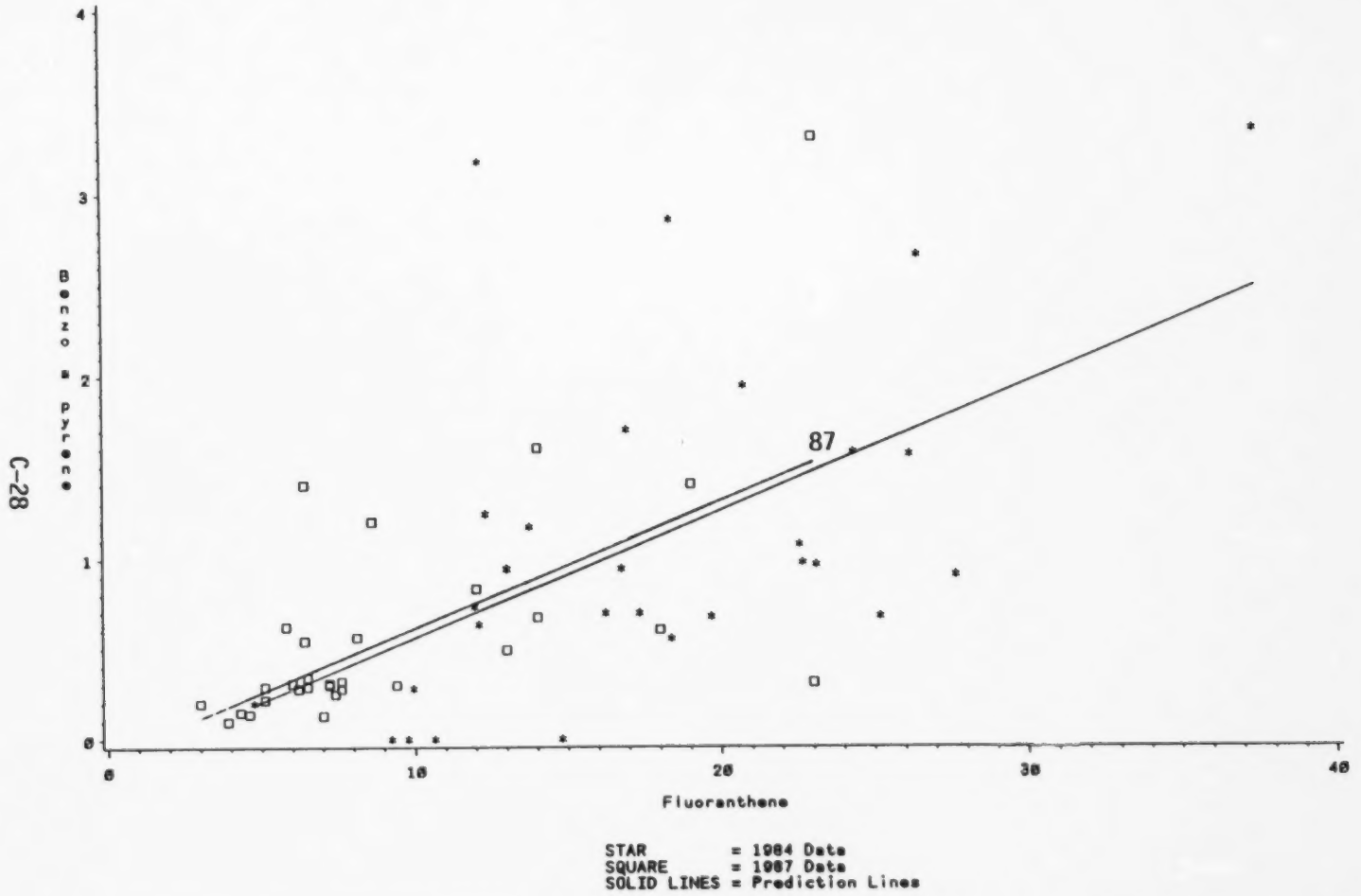


Figure C-27. Comparison of 1984 and 1987 Study Data for Predicting Benzo(a)pyrene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).

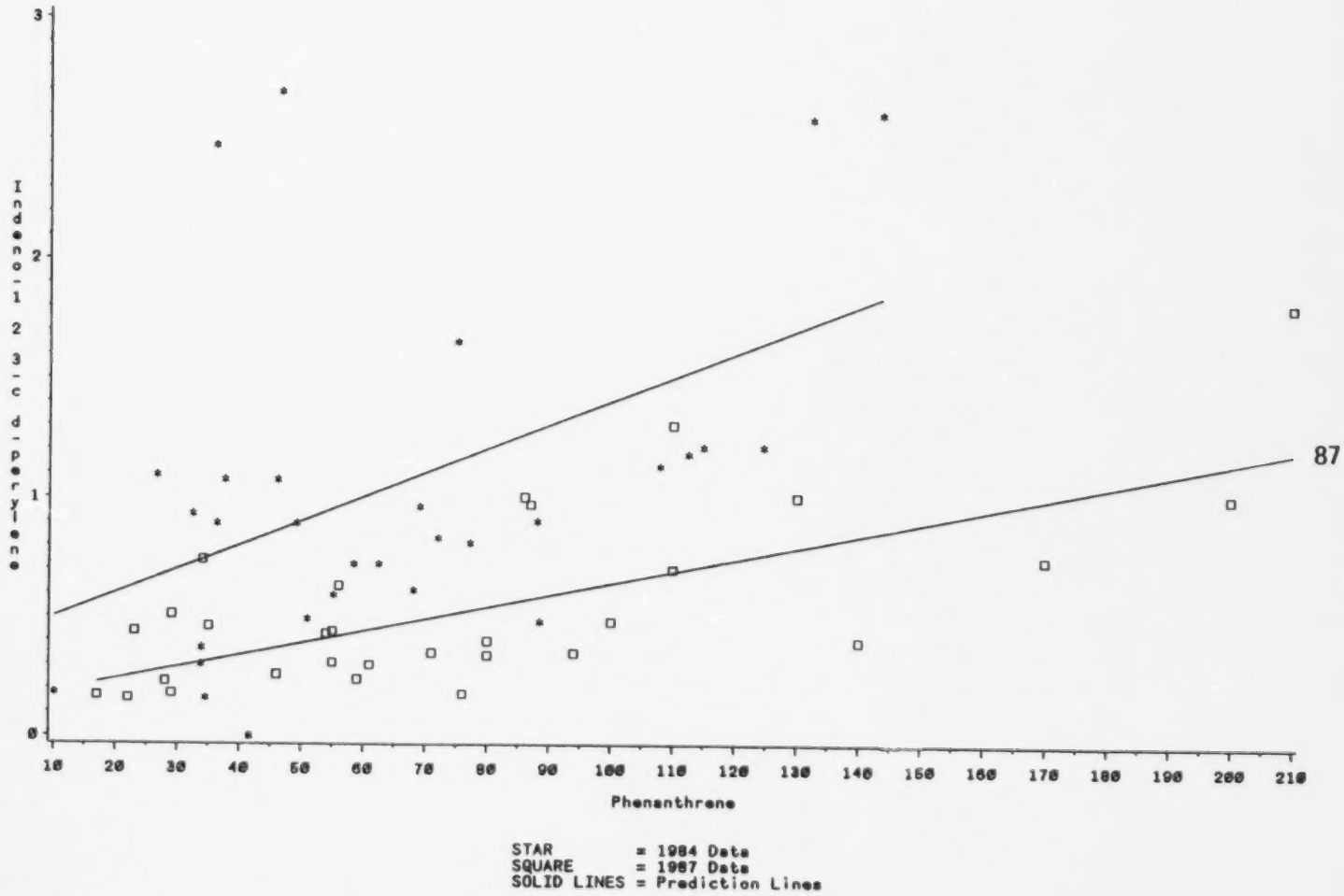


Figure C-28. Comparison of 1984 and 1987 Study Data for Predicting Indeno(1,2,3-c,d)perylene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

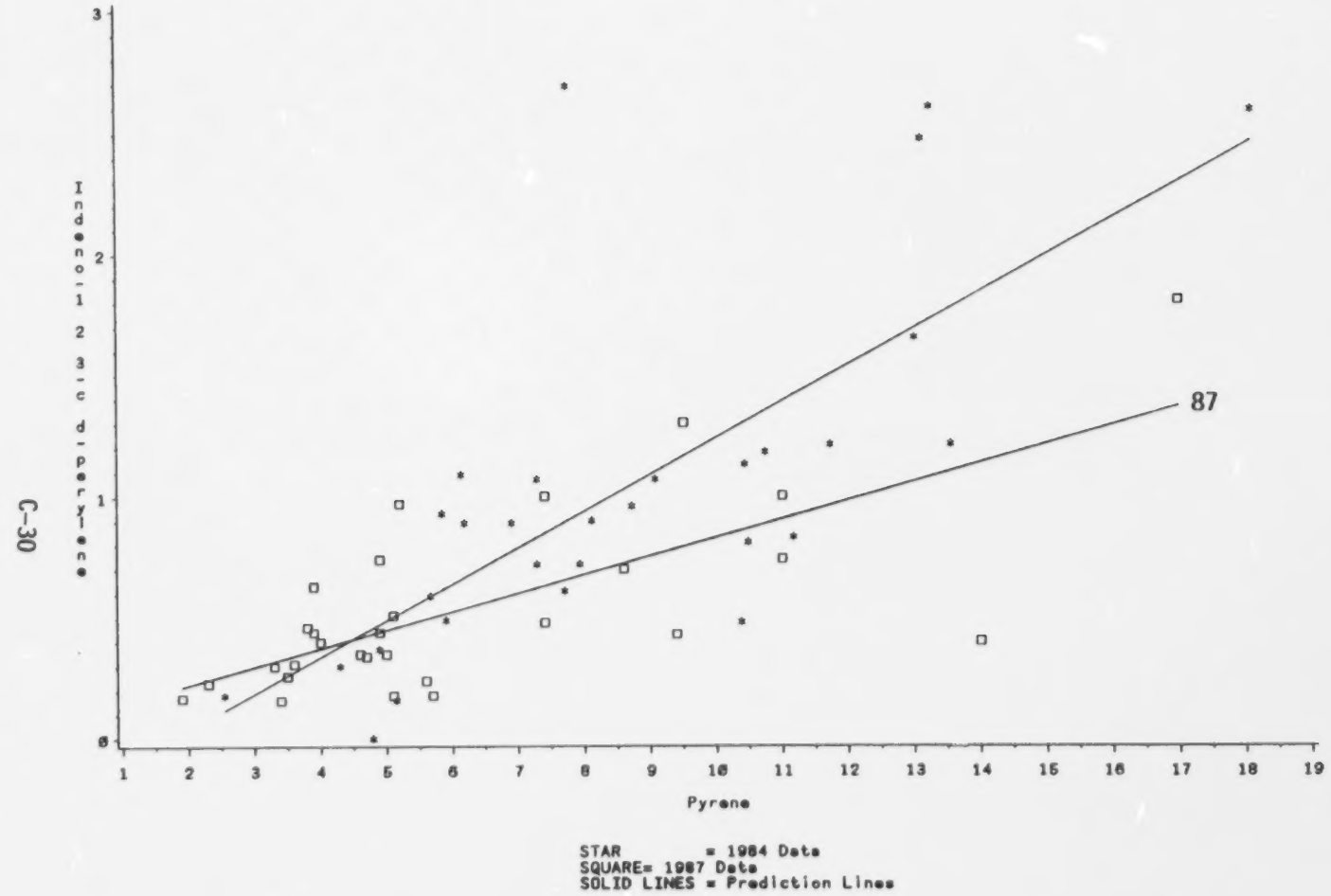


Figure C-29. Comparison of 1984 and 1987 Study Data for Predicting Indeno(1,2,3-c,d)perylene Concentration Levels from Measured Levels of Pyrene (ng/m3).

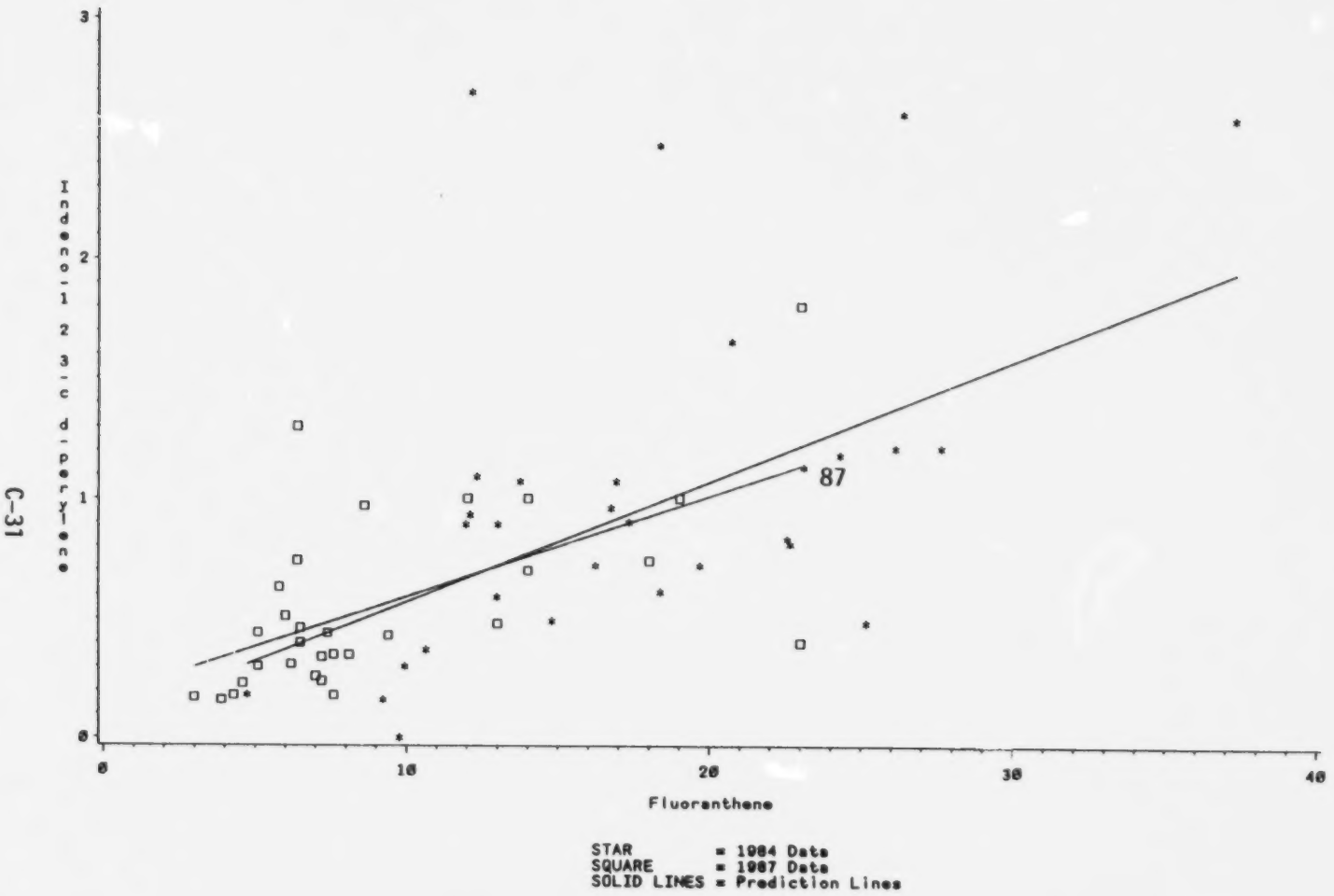


Figure C-30. Comparison of 1984 and 1987 Study Data for Predicting Indeno(1,2,3-c,d)perylene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).

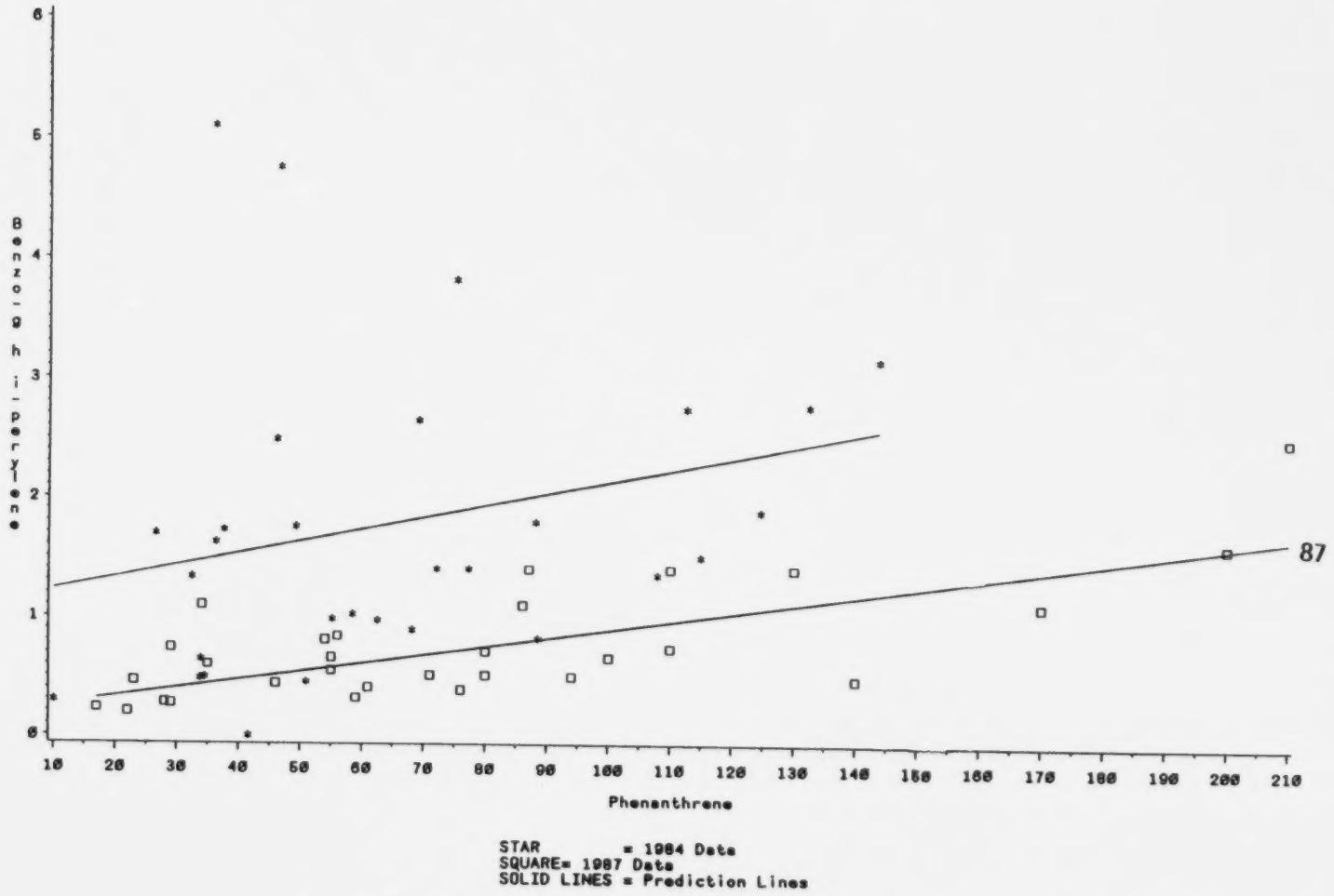


Figure C-31. Comparison of 1984 and 1987 Study Data for Predicting Benzo(g,h,i)perylene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

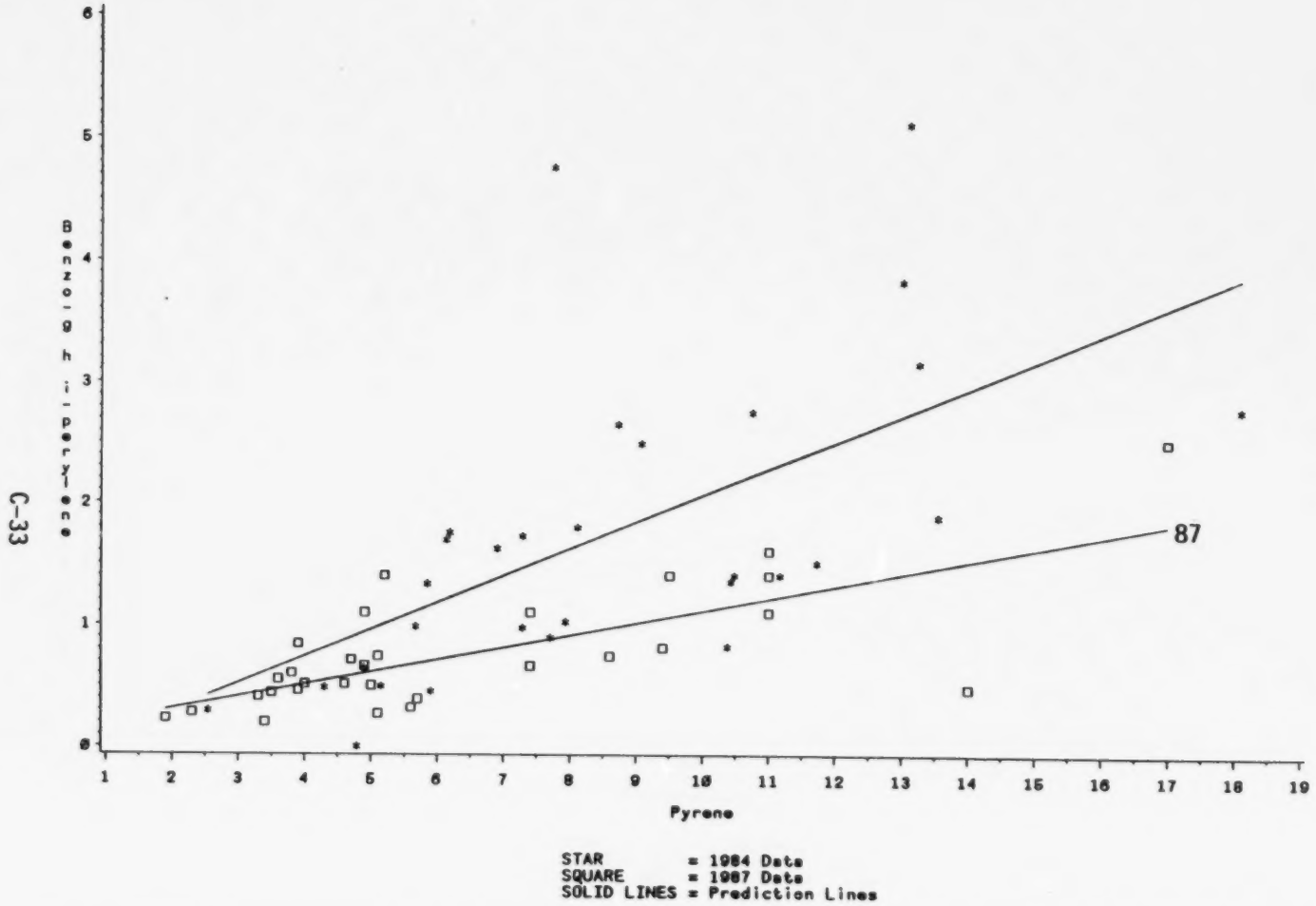


Figure C-32. Comparison of 1984 and 1987 Study Data for Predicting Benzo(g,h,i)perylene Concentration Levels from Measured Levels of Pyrene (ng/m^3).

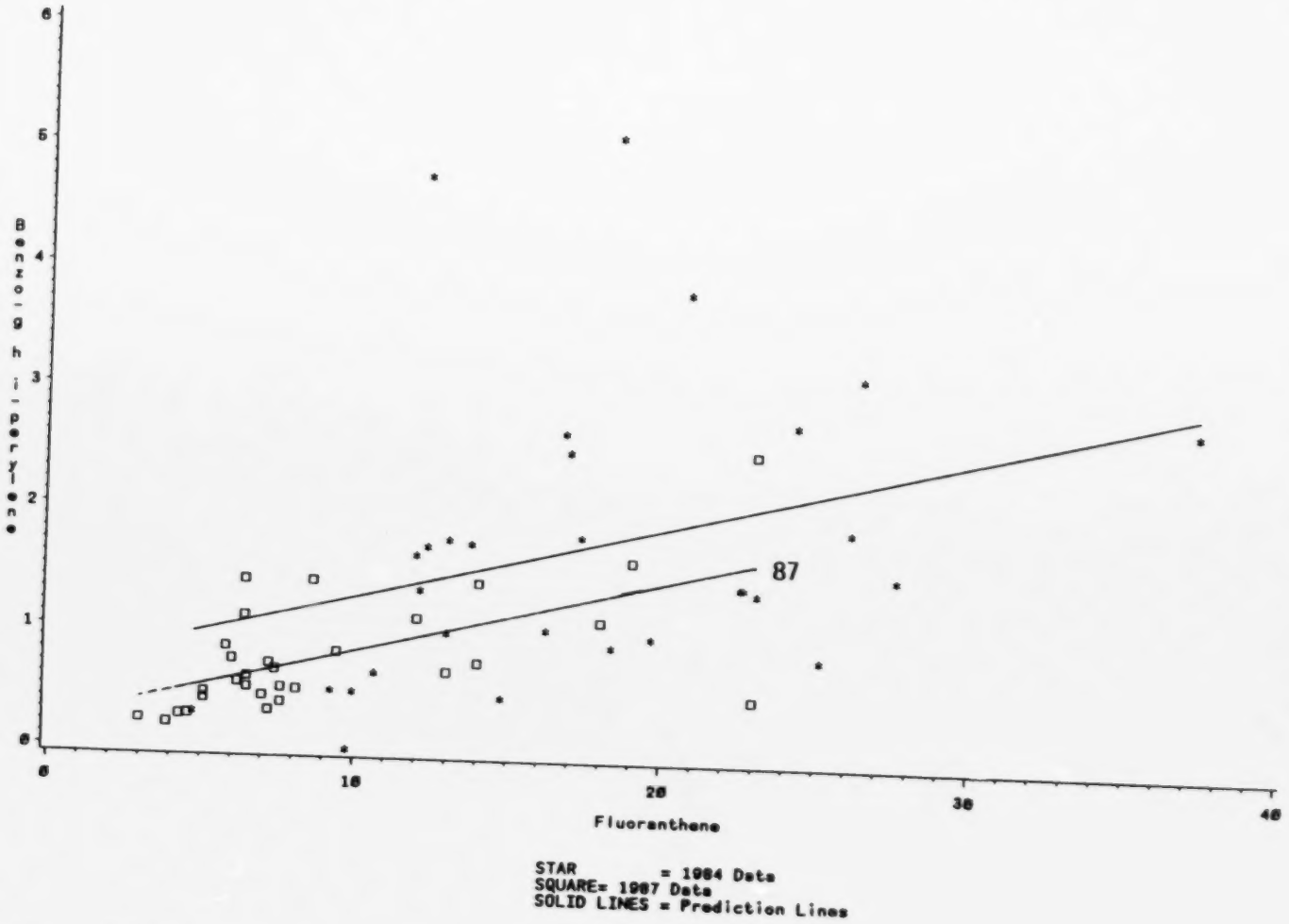


Figure C-33. Comparison of 1984 and 1987 Study Data for Predicting Benzo(g,h,i)perylene Concentration Levels from Measured Levels f Fluoranthene (ng/m3).

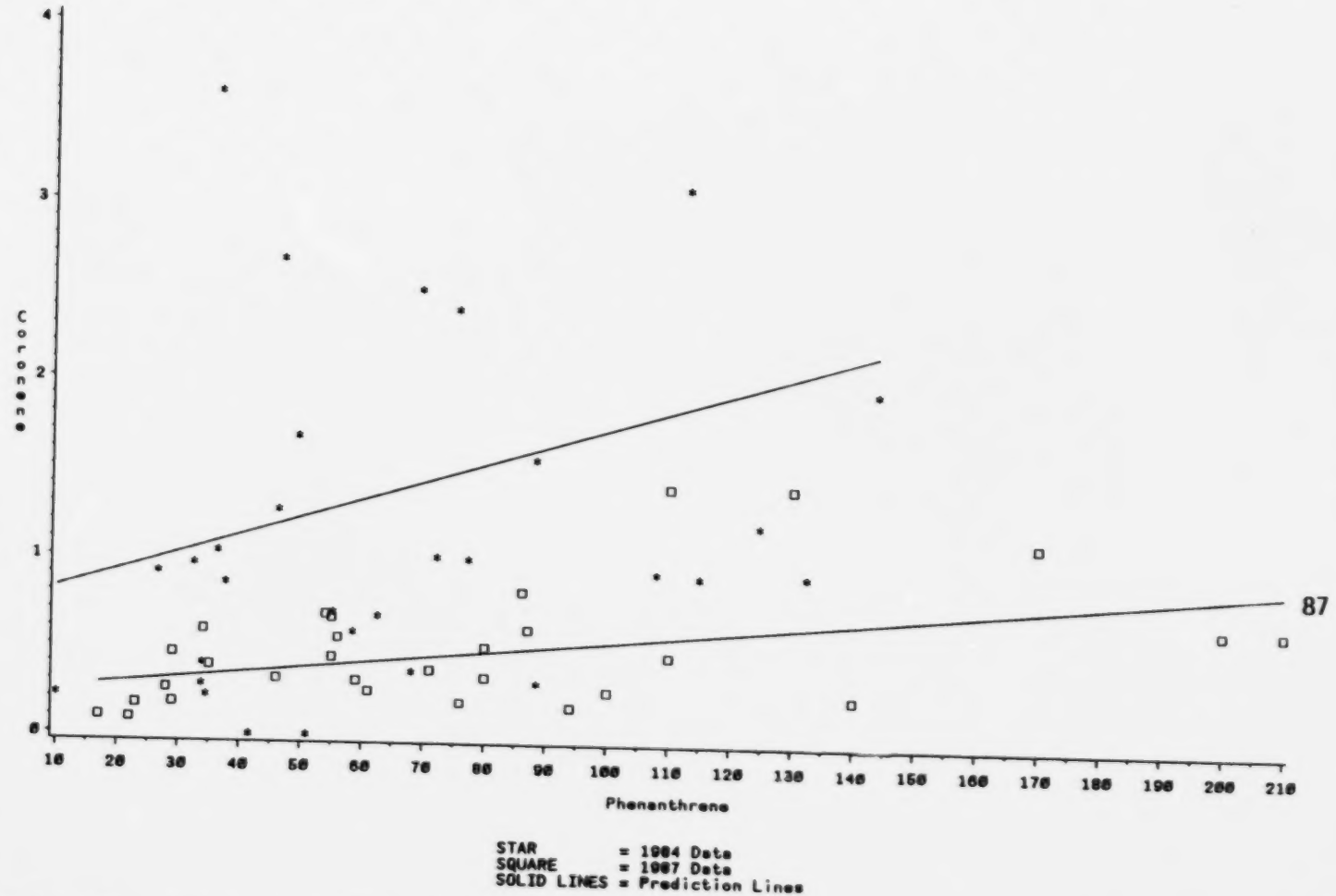


Figure C-34. Comparison of 1984 and 1987 Study Data for Predicting Coronene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

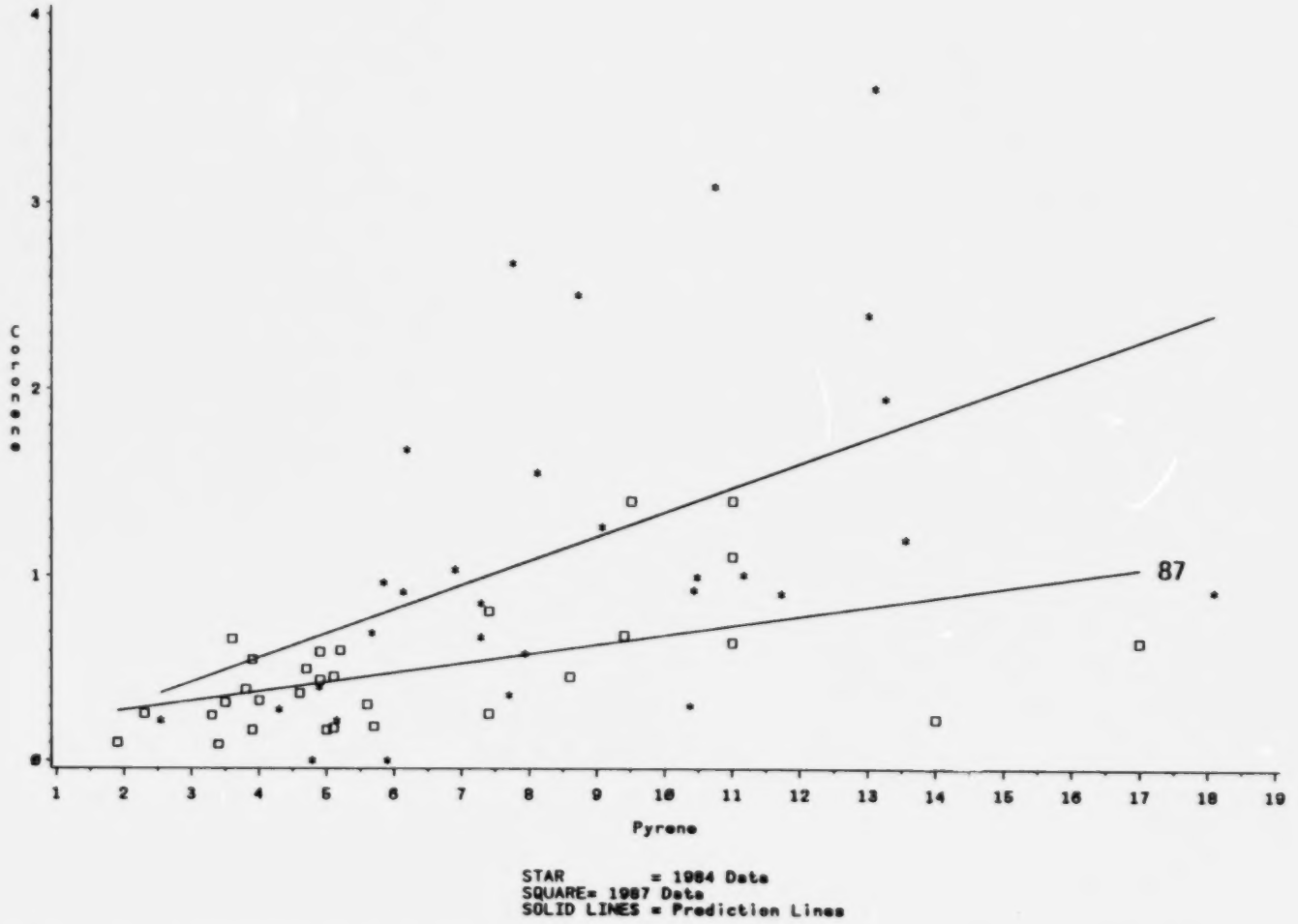


Figure C-35. Comparison of 1984 and 1987 Study Data for Predicting Coronene Concentration Levels from Measured Levels of Pyrene (ng/m^3).

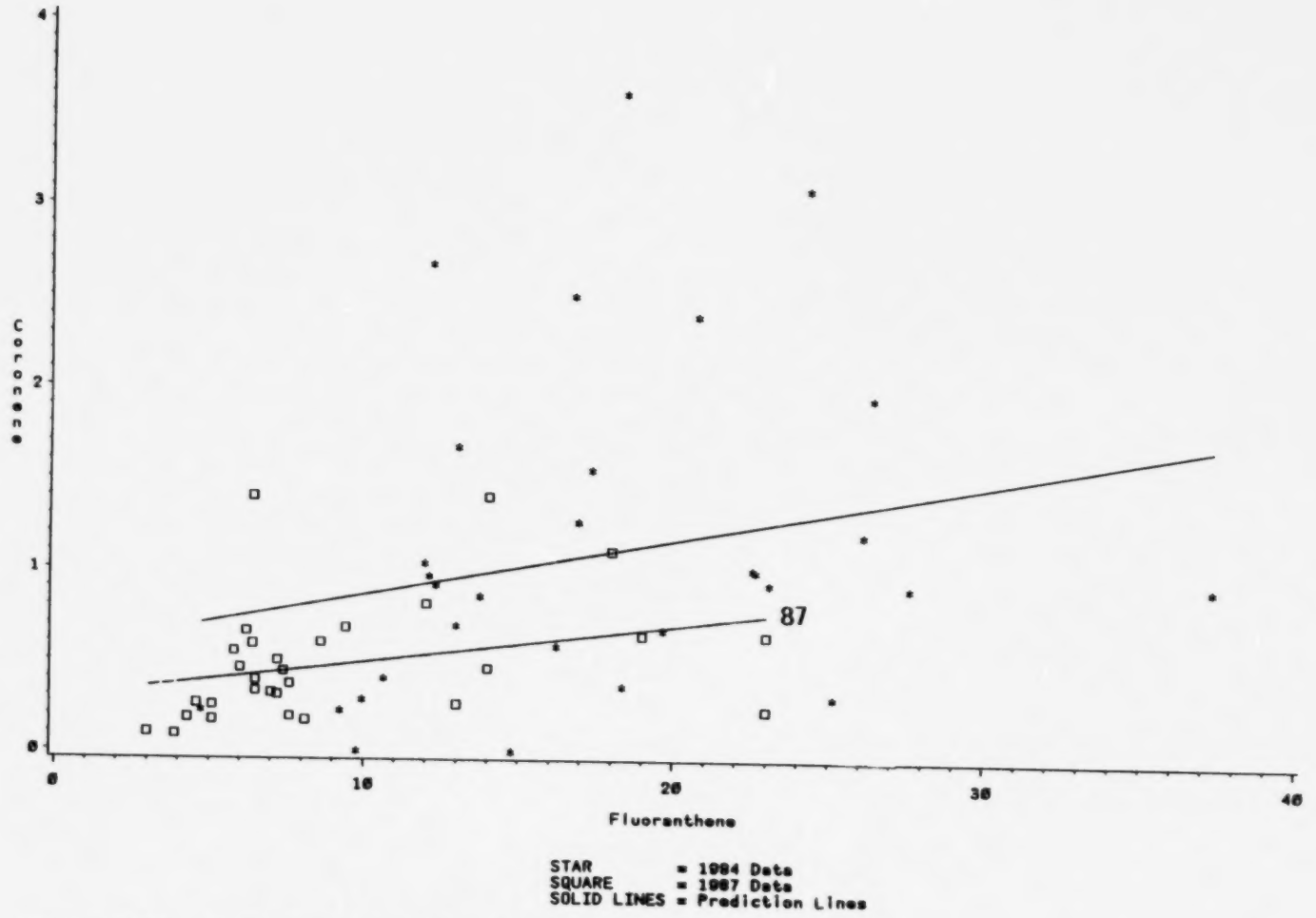


Figure C-36. Comparison of 1984 and 1987 Study Data for Predicting Coronene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

APPENDIX D

Combined 1984 and 1987 Study Data For Predicting PAH Target Compound Levels From Measured Levels of Potential PAH Marker Compounds

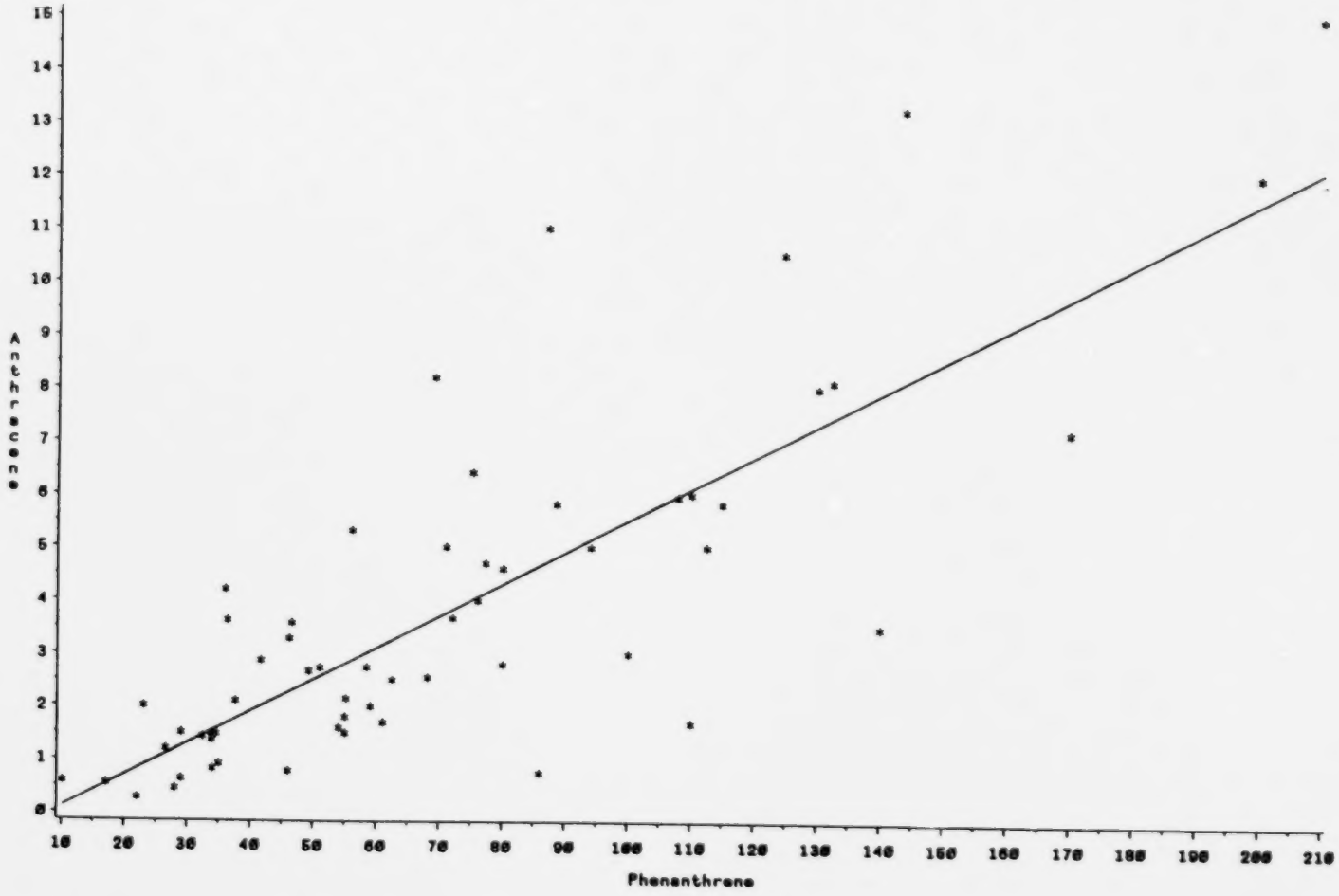


Figure D-1. Combined 1984 and 1987 Study Data for Predicting Anthracene Concentration Levels from Measured Levels of Phenanthrene (ng/m^3).

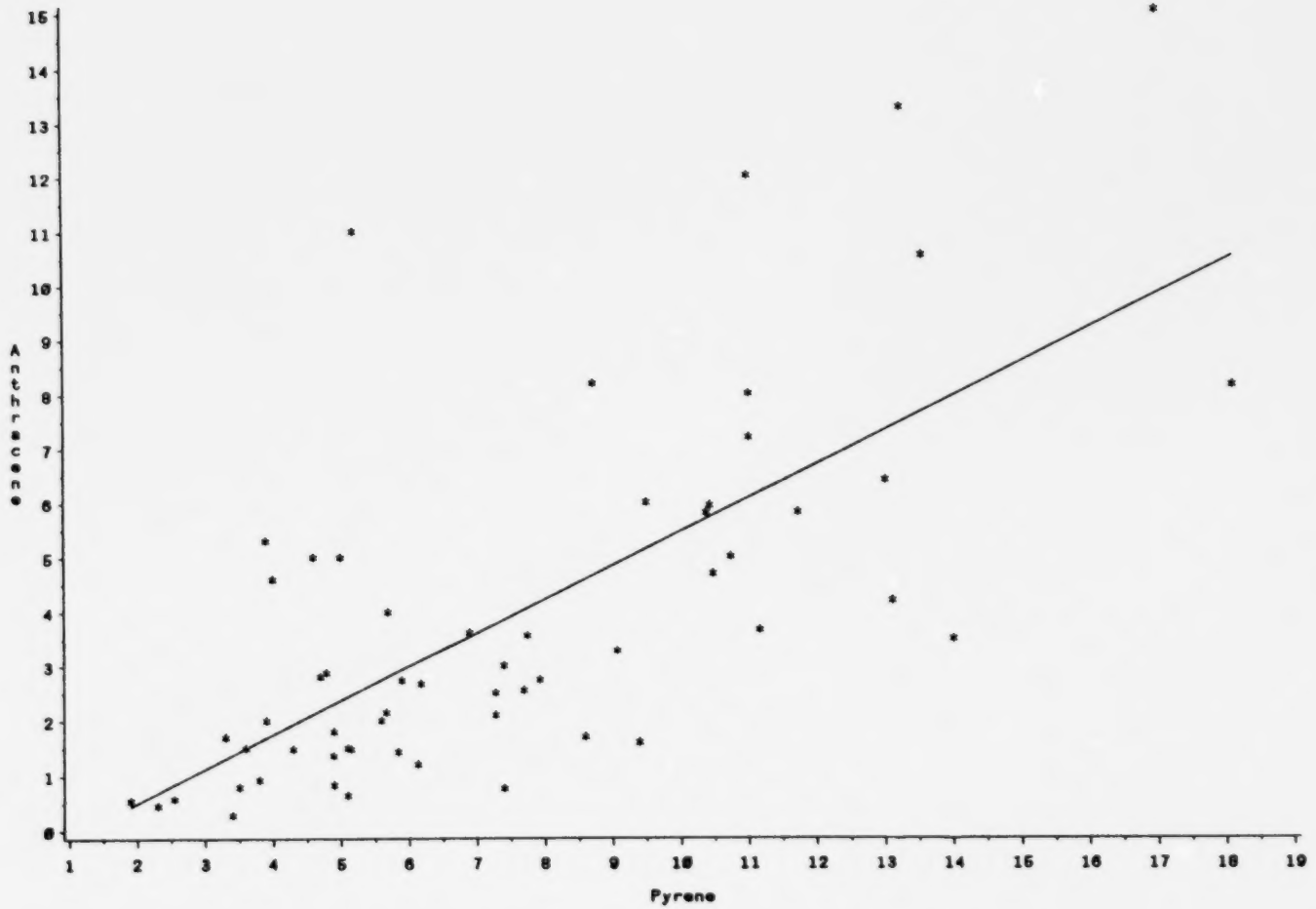


Figure D-2. Combined 1984 and 1987 Study Data for Predicting Anthacene Concentration Levels from Measured Levels of Pyrene (ng/m^3).

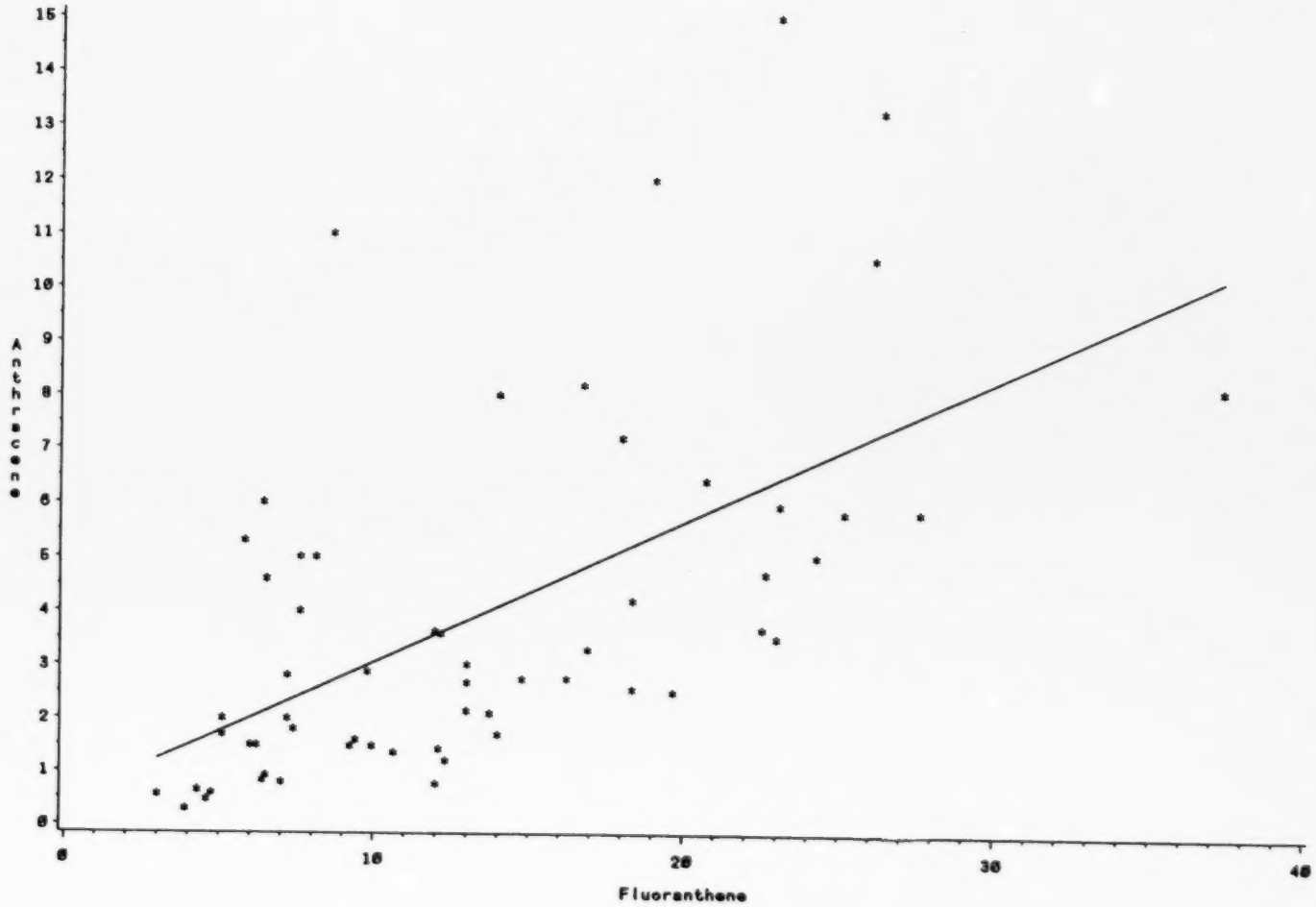


Figure D-3. Combined 1984 and 1987 Study Data for Predicting Anthracene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

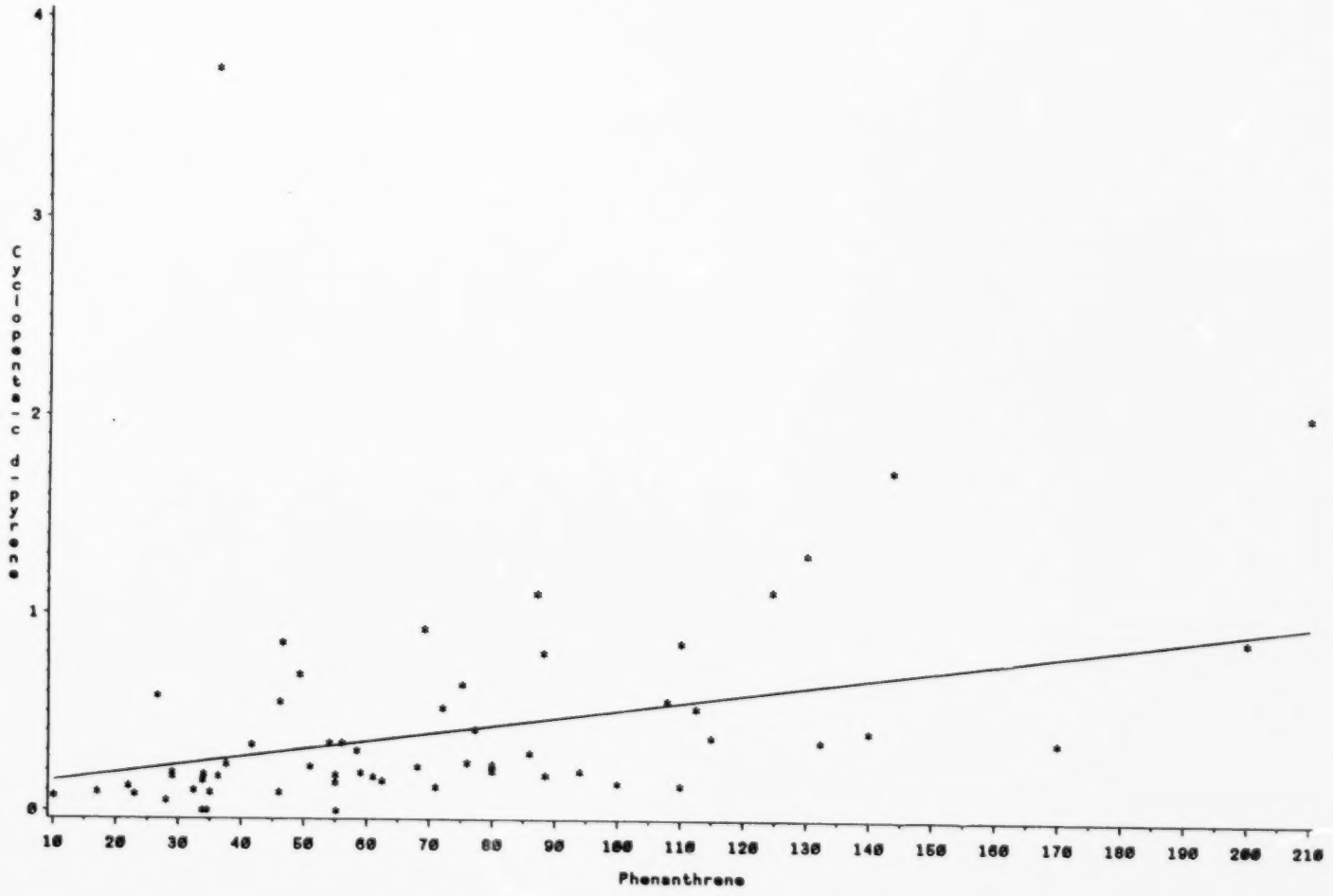


Table D-4. Combined 1984 and 1987 Study Data for Predicting Cyclopenta(c,d)pyrene Concentration Levels from Measured Levels of Phenanthrene (ng/m^3).

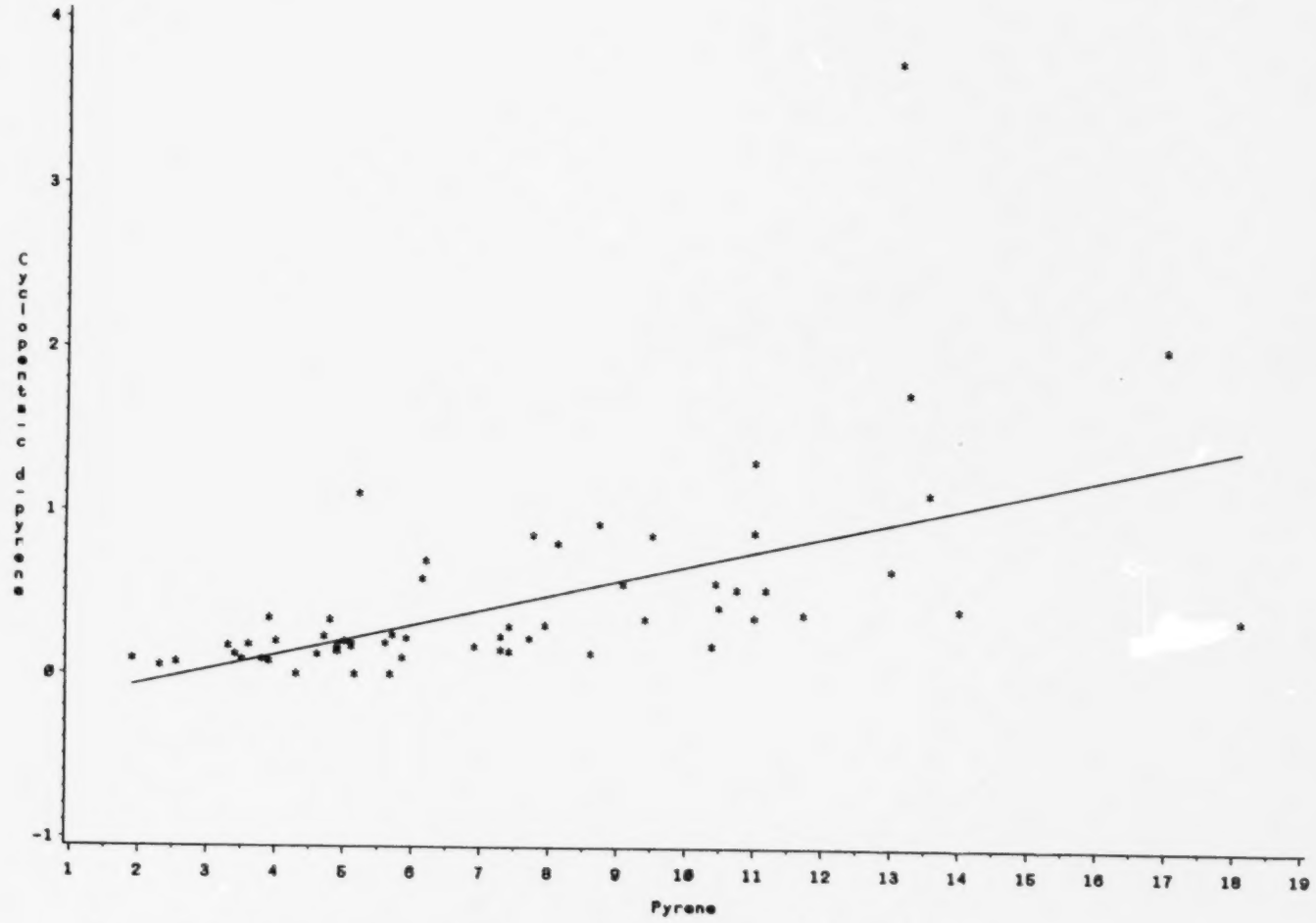


Figure D-5. Combined 1984 and 1987 Study Data for Predicting Cyclopenta(c,d)pyrene Concentration Levels from Measured Levels of Pyrene (ng/m3).

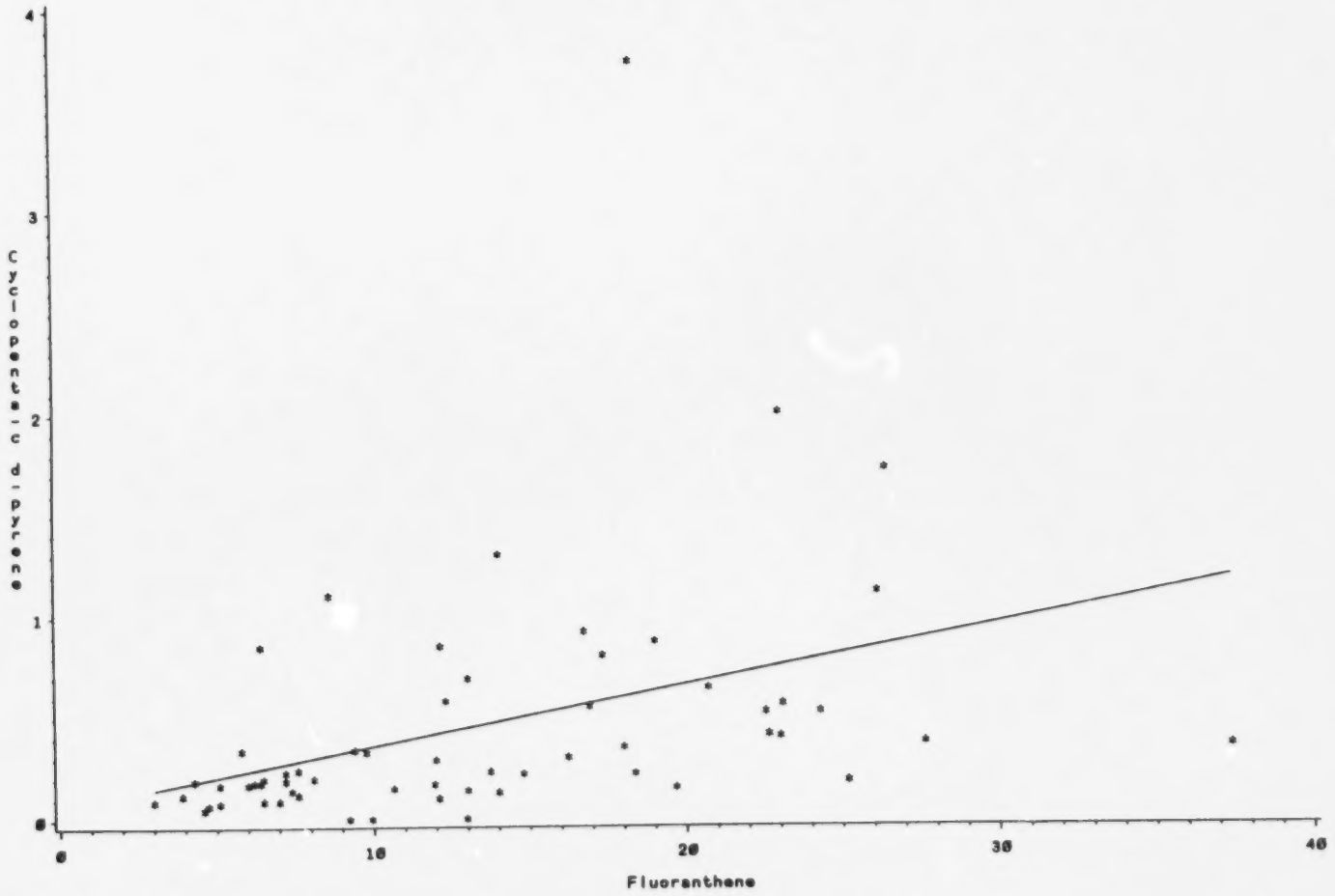


Figure D-6. Combined 1984 and 1987 Study Data for Predicting Cyclopenta(c,d)pyrene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

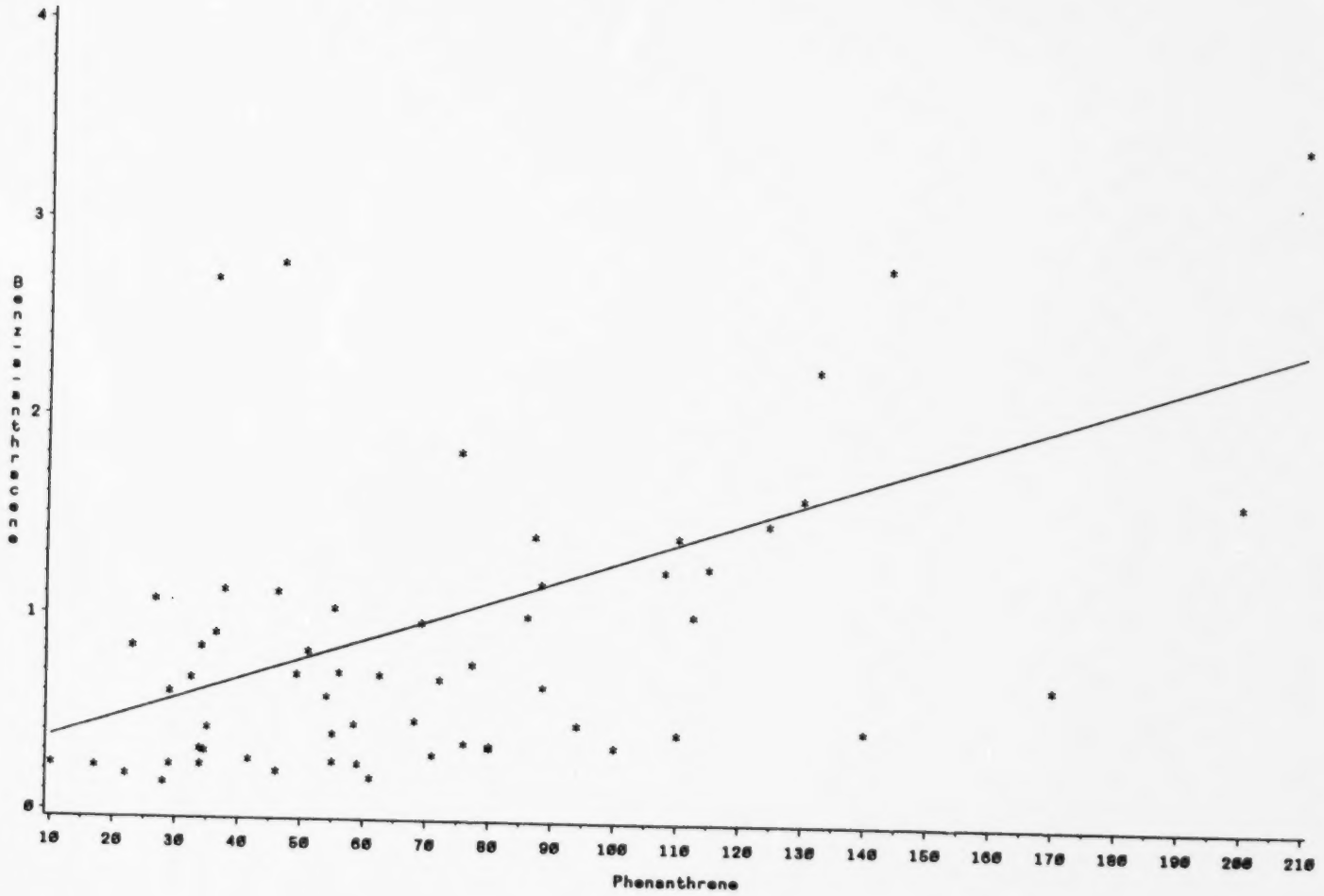


Figure D-7. Combined 1984 and 1987 Study Data for Predicting Benz(a)anthracene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

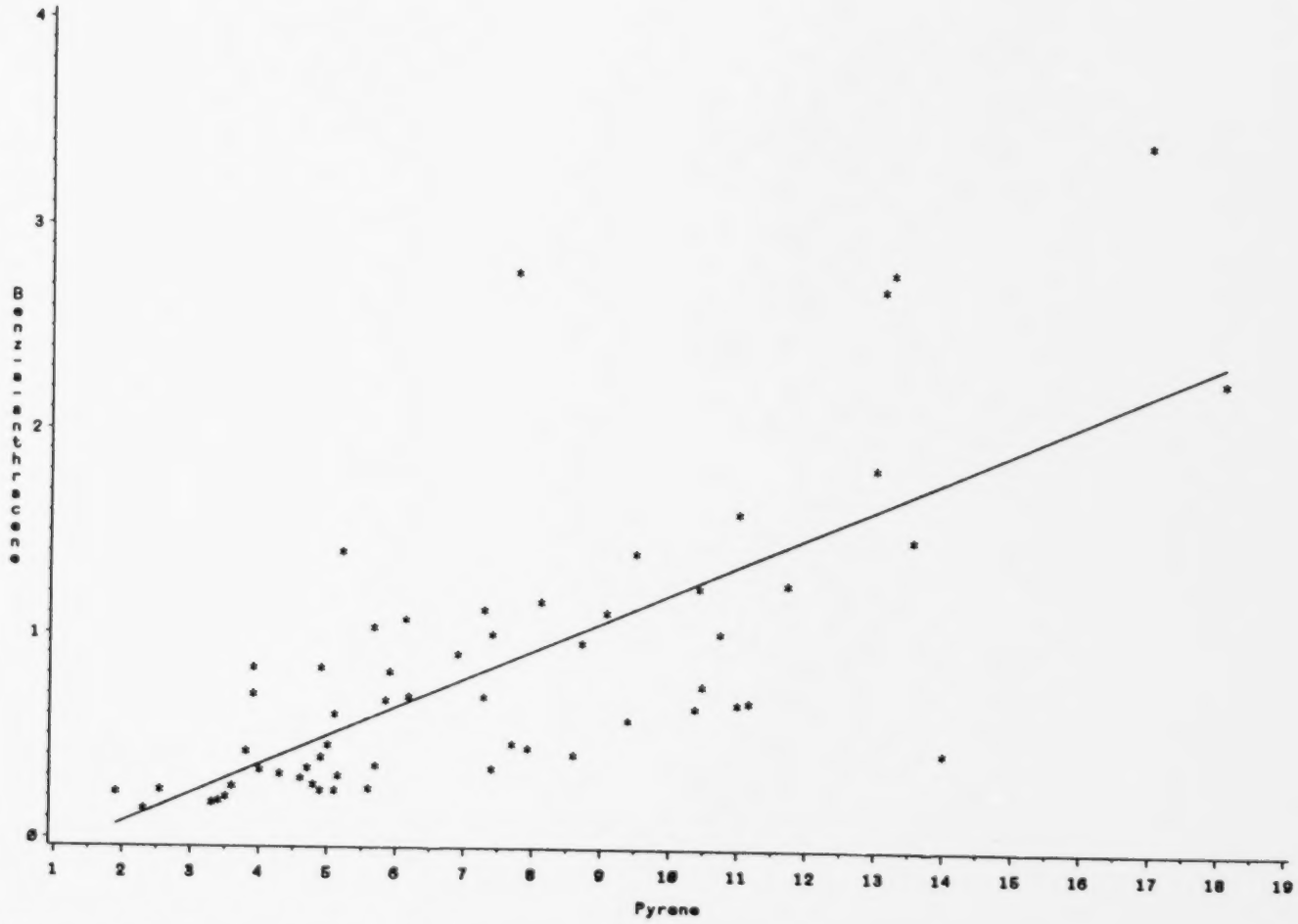


Figure D-8. Combined 1984 and 1987 Study Data for Predicting Benz(a)anthracene Concentration Levels from Measured Levels of Pyrene (ng/m3).

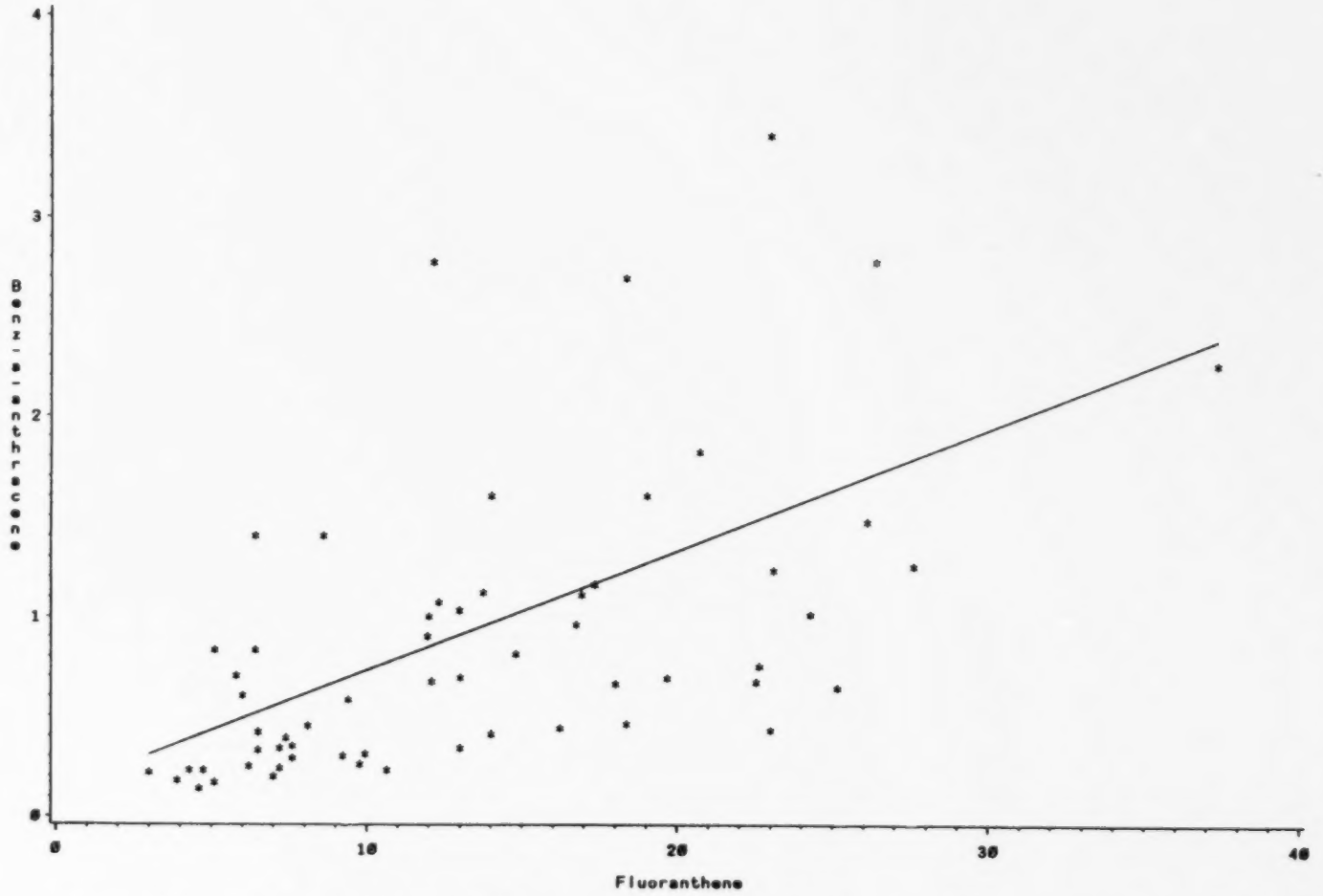


Figure D-9. Combined 1984 and 1987 Study Data for Predicting Benz(a)anthracene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).

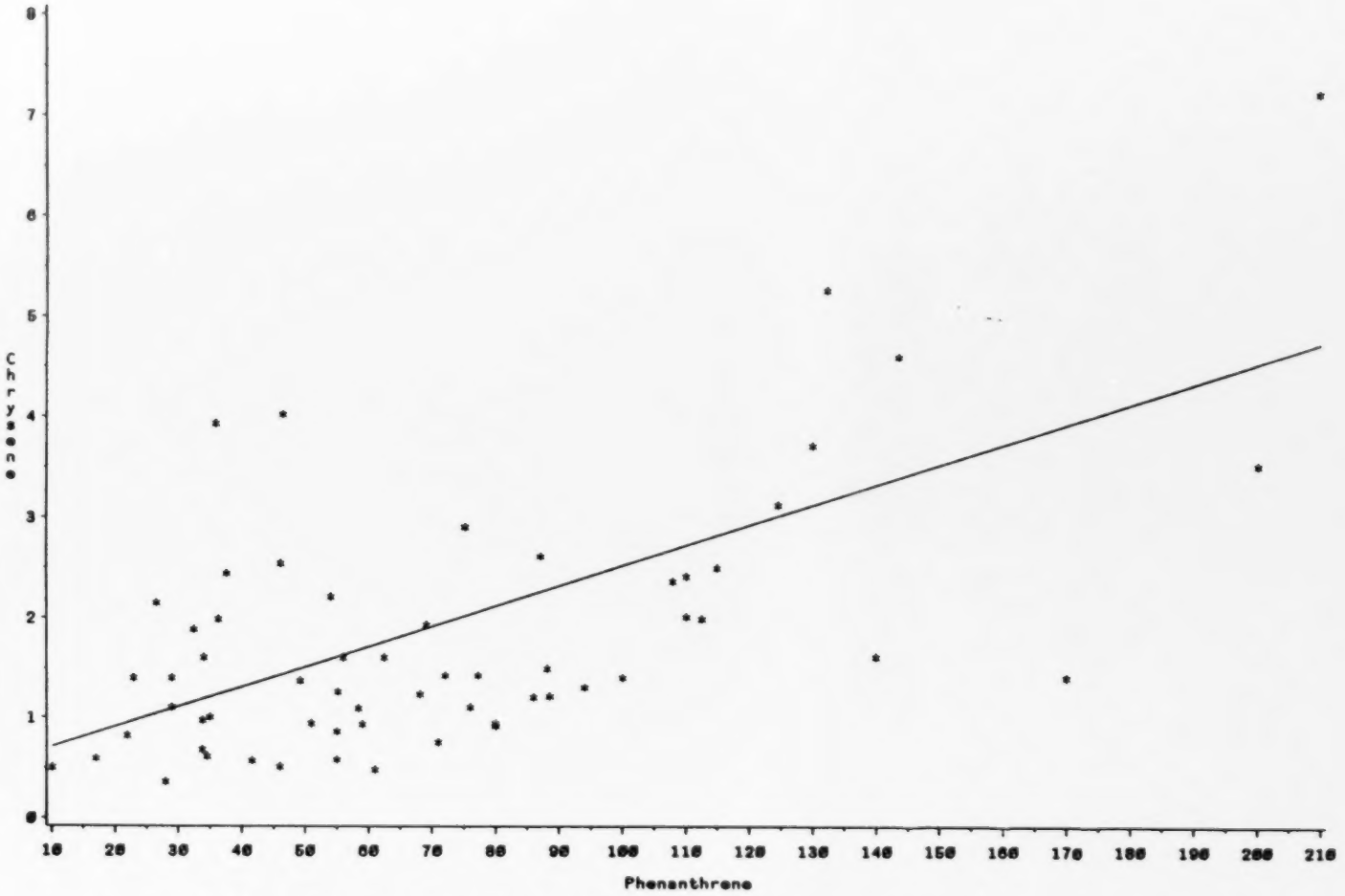


Figure D-10. Combined 1984 and 1987 Study Data for Predicting Chrysene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

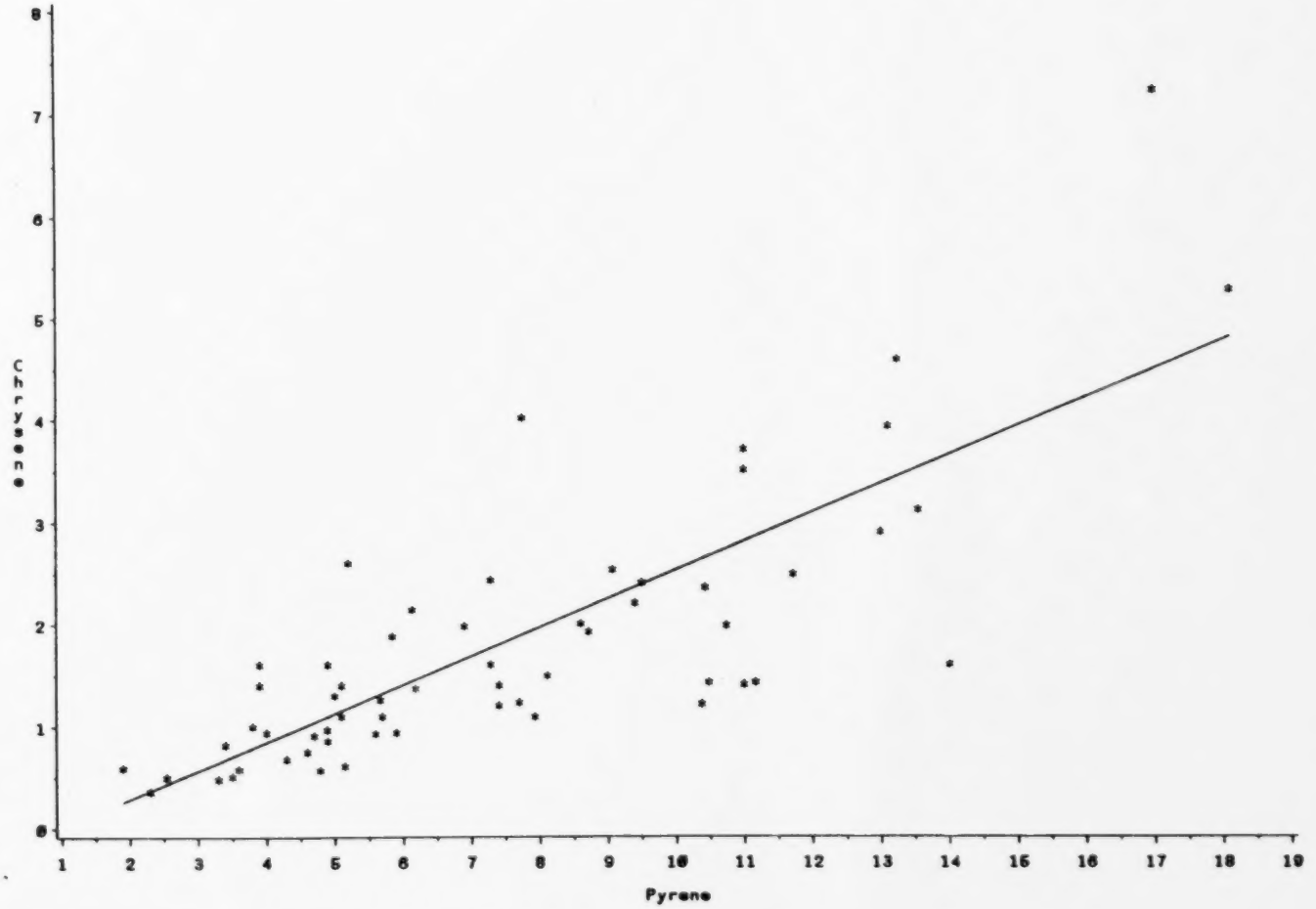


Figure D-11. Combined 1984 and 1987 Study Data for Predicting Chrysene Concentration Levels from Measured Levels of Pyrene (ng/m3).

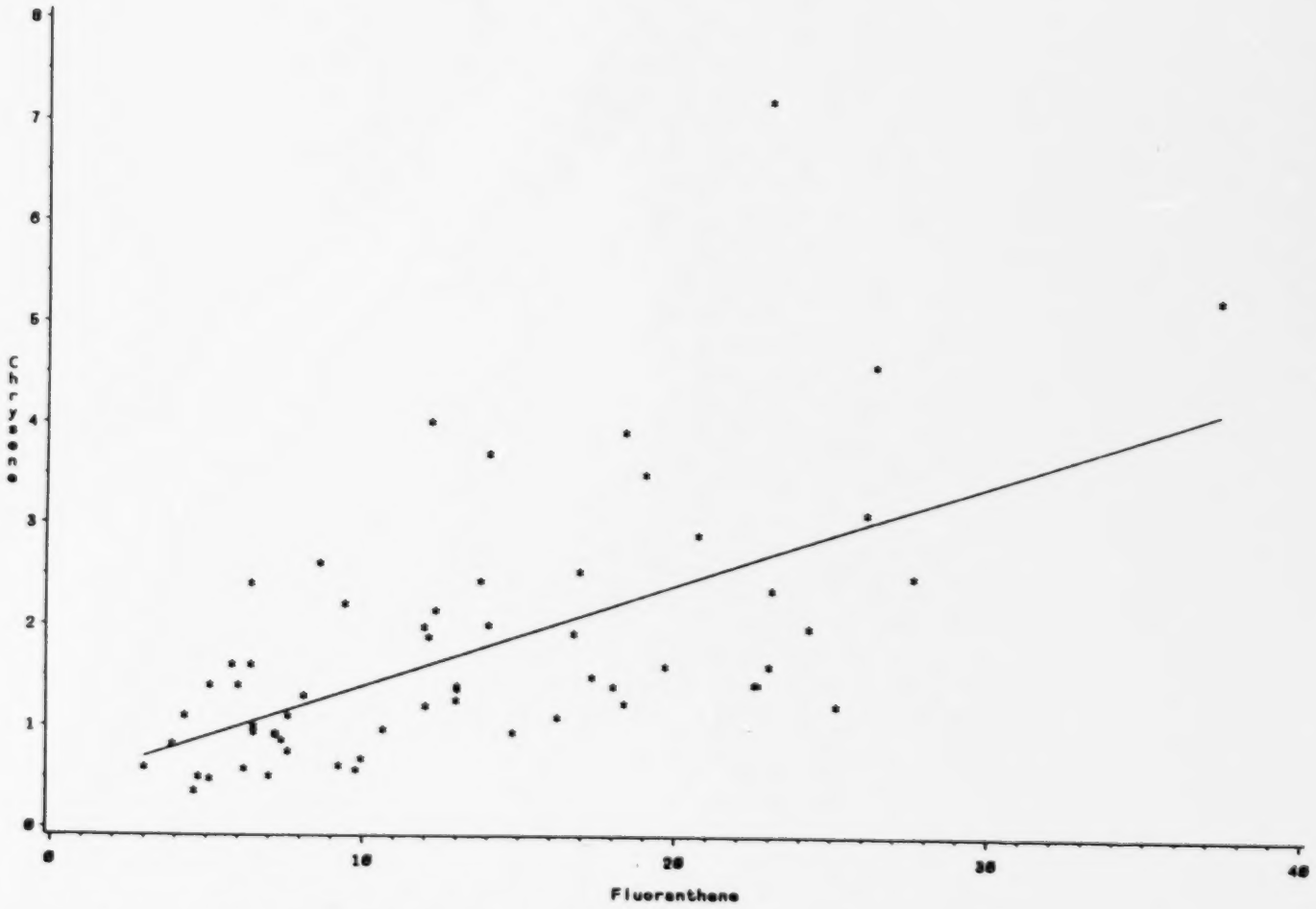


Figure D-12. Combined 1984 and 1987 Study Data for Predicting Chrysene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).

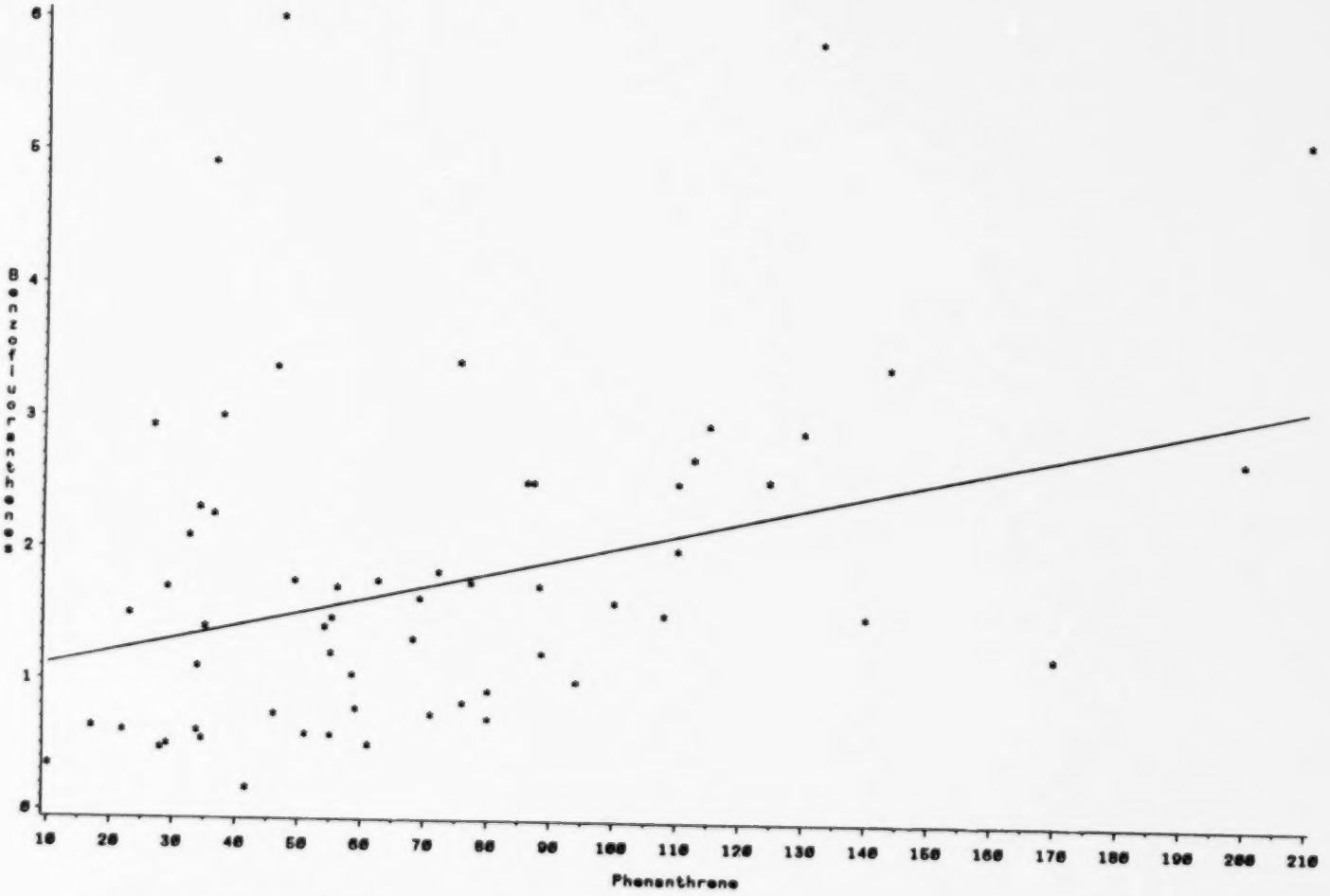


Figure D-13. Combined 1984 and 1987 Study Data for Predicting Benzofluoranthenes Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

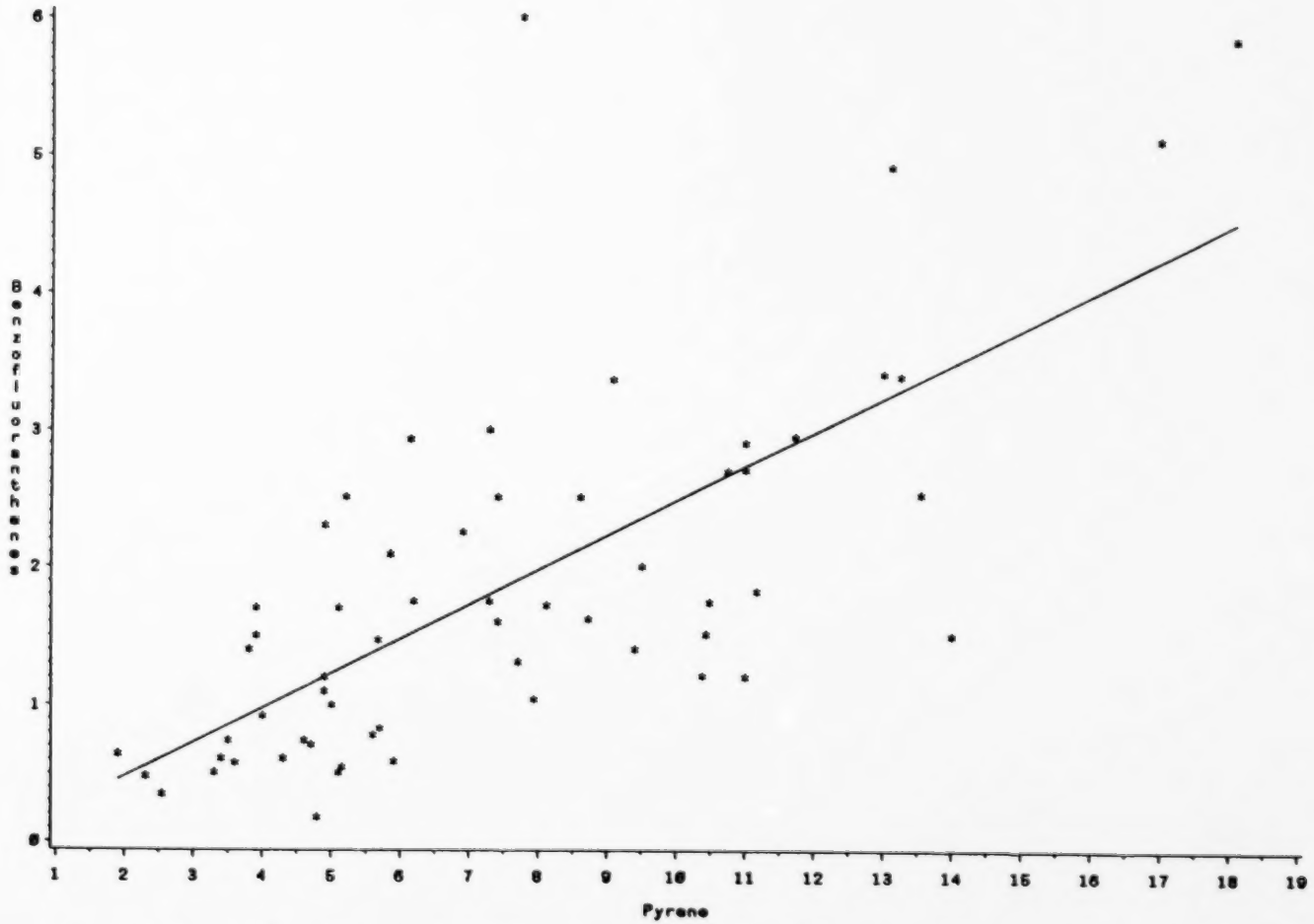


Figure D-14. Combined 1984 and 1987 Study Data for Predicting Benzofluoranthenes Concentration Levels from Measured Levels of Pyrene (ng/m3).

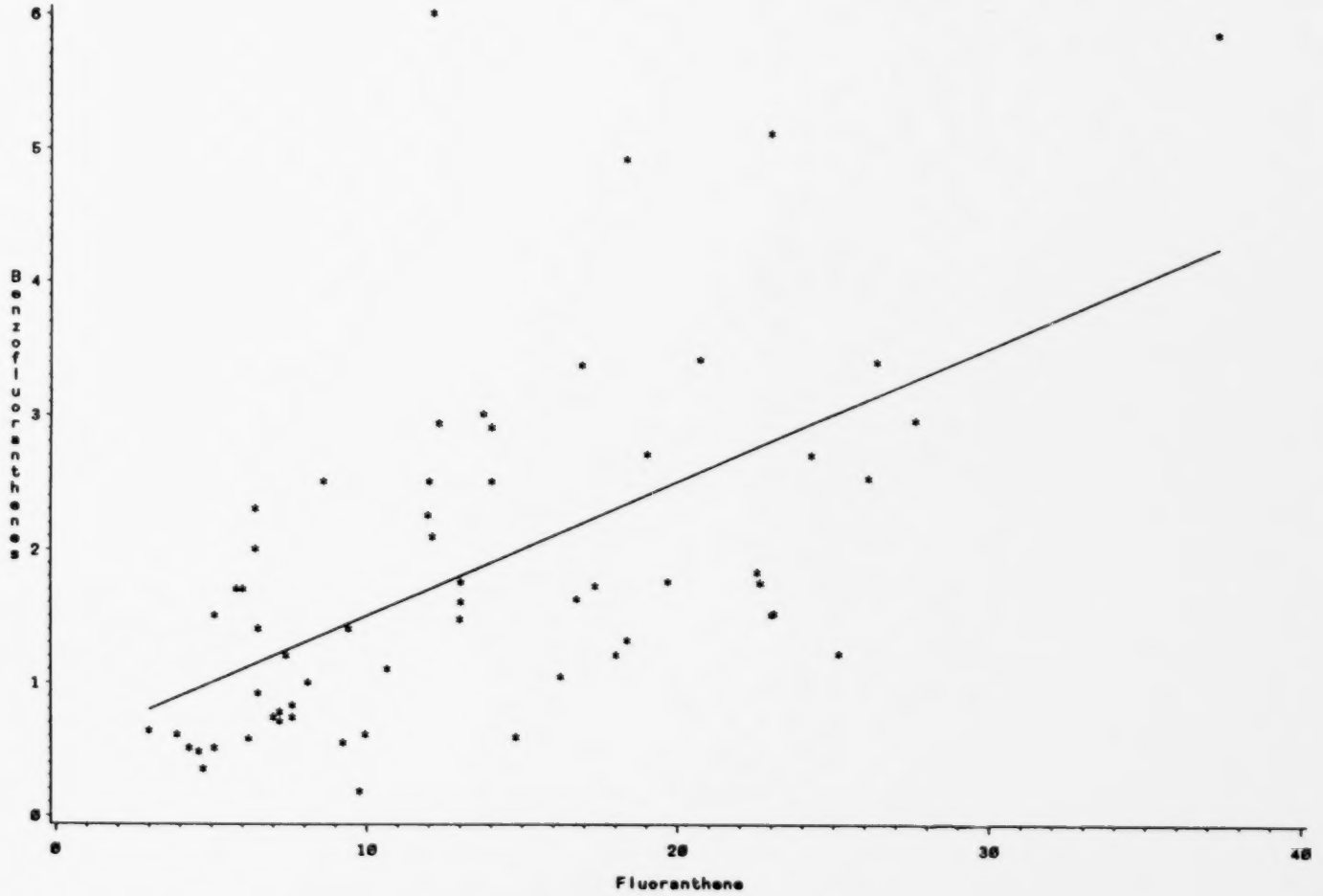


Figure D-15. Combined 1984 and 1987 Study Data for Predicting Benzofluoranthenes Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

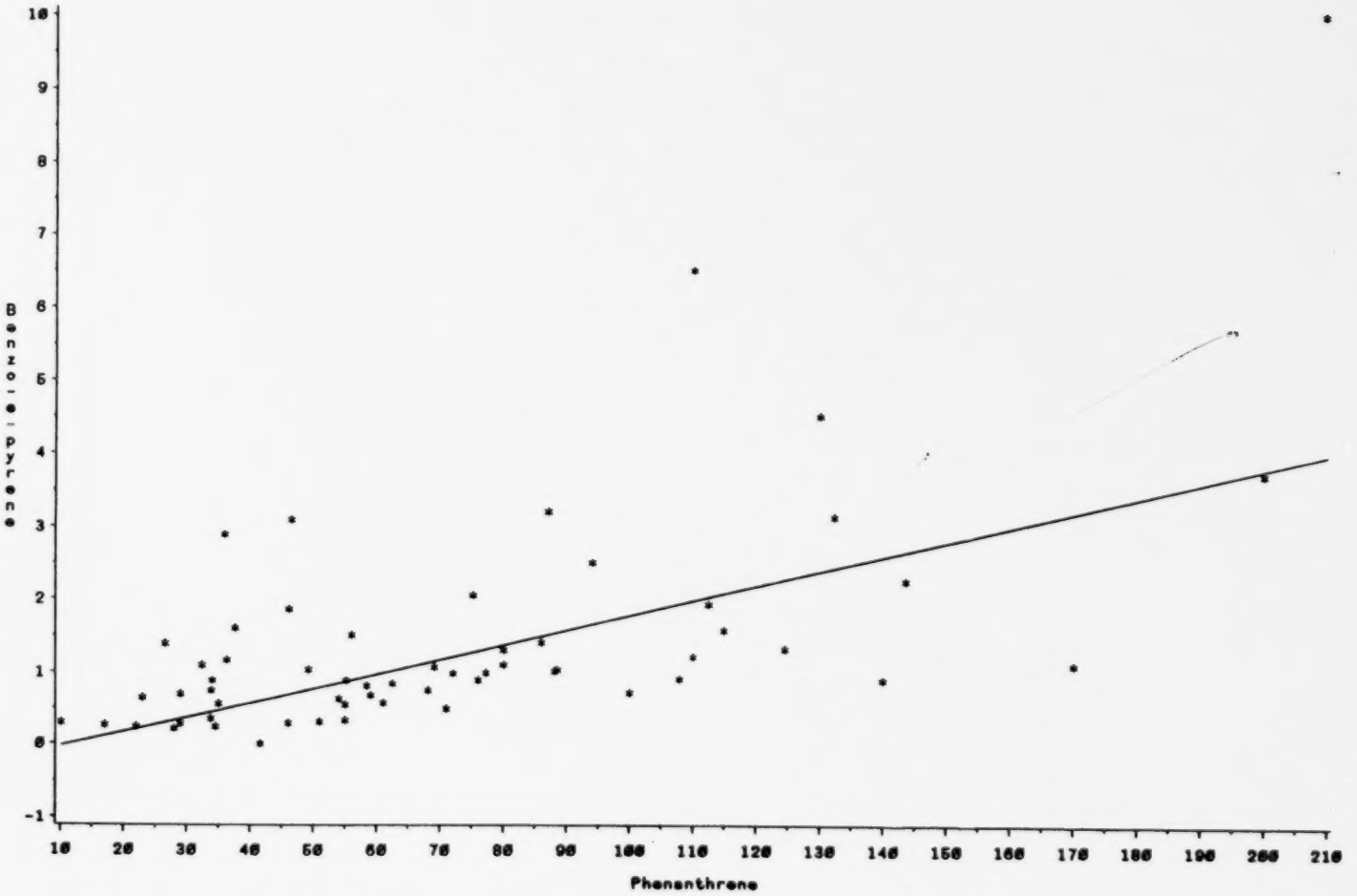


Figure D-16. Combined 1984 and 1987 Study Data for Predicting Benzo(e)pyrene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

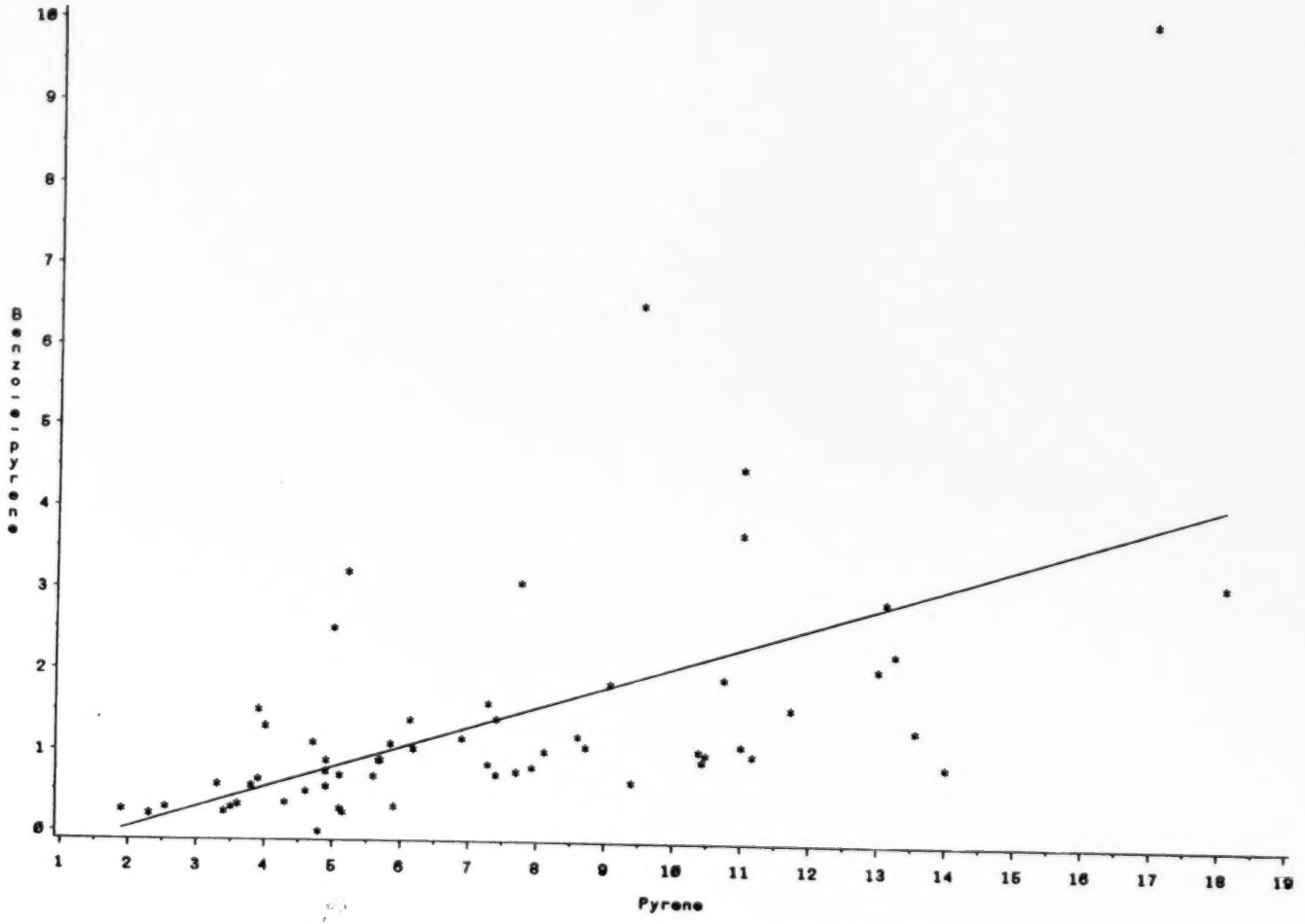


Figure D-17. Combined 1984 and 1987 Study Data for Predicting Benzo(e)pyrene Concentration Levels from Measured Levels of Pyrene (ng/m3).

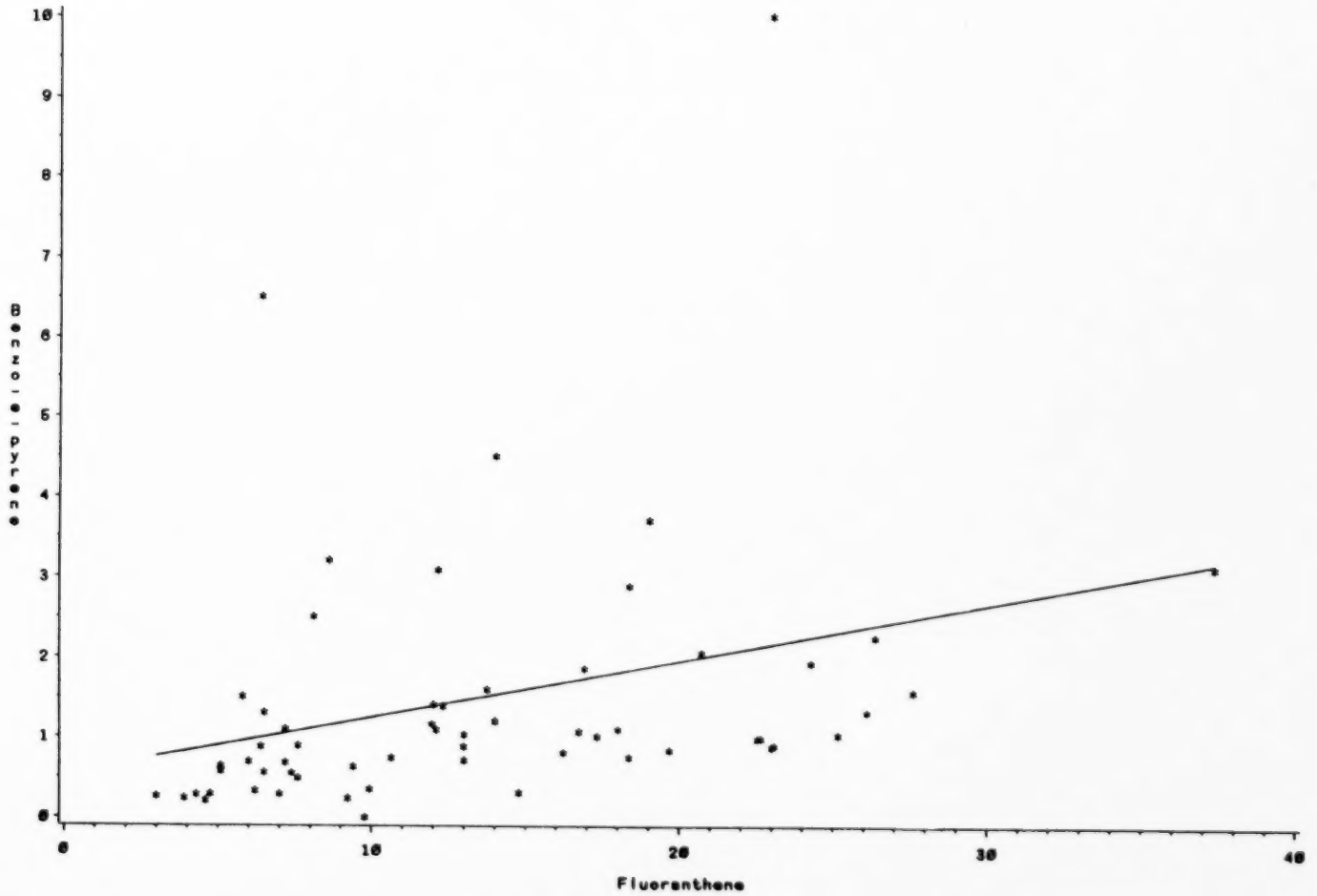


Figure D-18. Combined 1984 and 1987 Study Data for Predicting Benzo(e)pyrene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

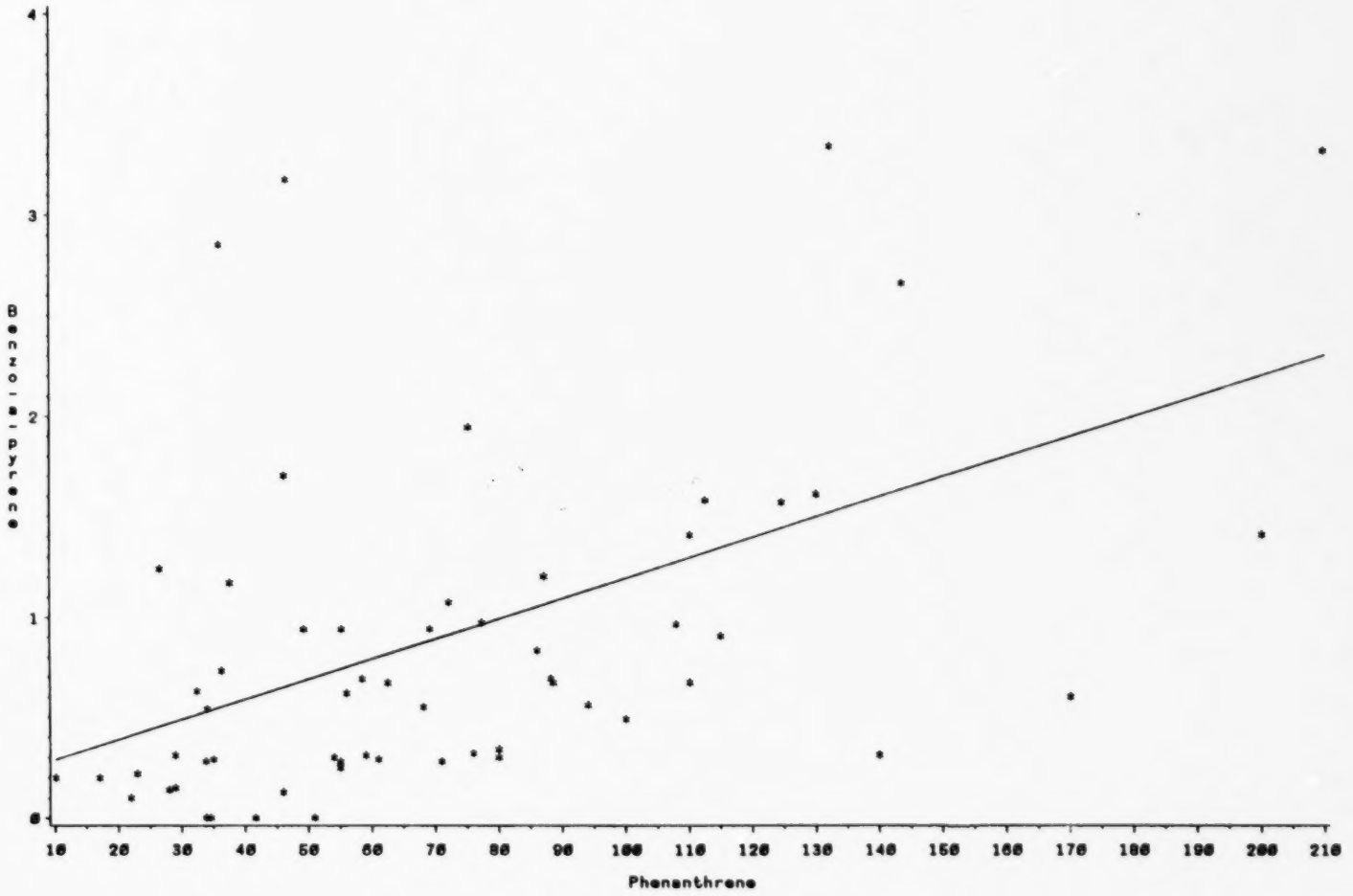


Figure D-19. Combined 1984 and 1987 Study Data for Predicting Benzo(a)pyrene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

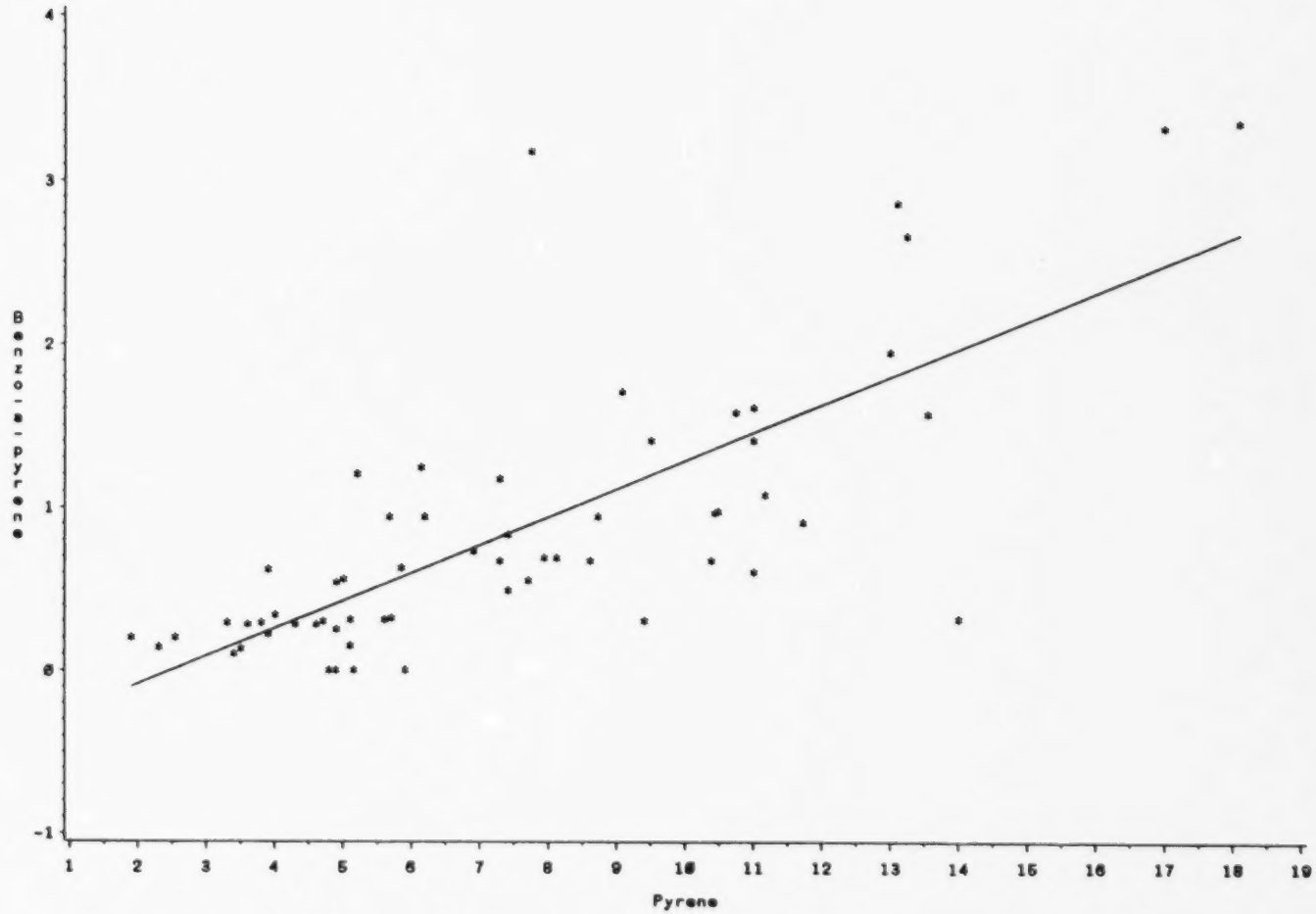


Figure D-20. Combined 1984 and 1987 Study Data for Predicting Benzo(a)pyrene Concentration Levels from Measured Levels of Pyrene (ng/m3).

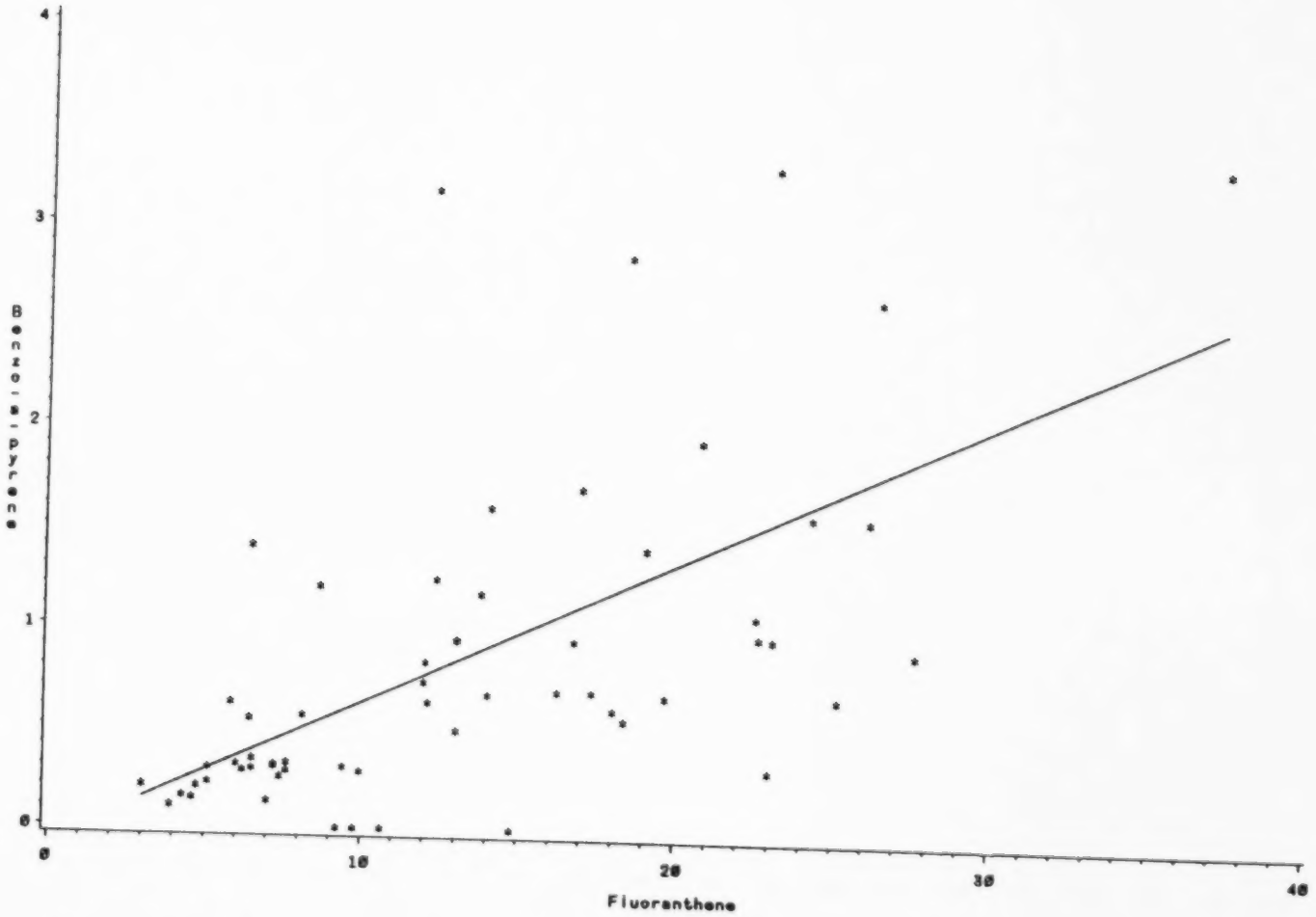


Figure D-21. Combined 1984 and 1987 Study Data for Predicting Benzo(a)pyrene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

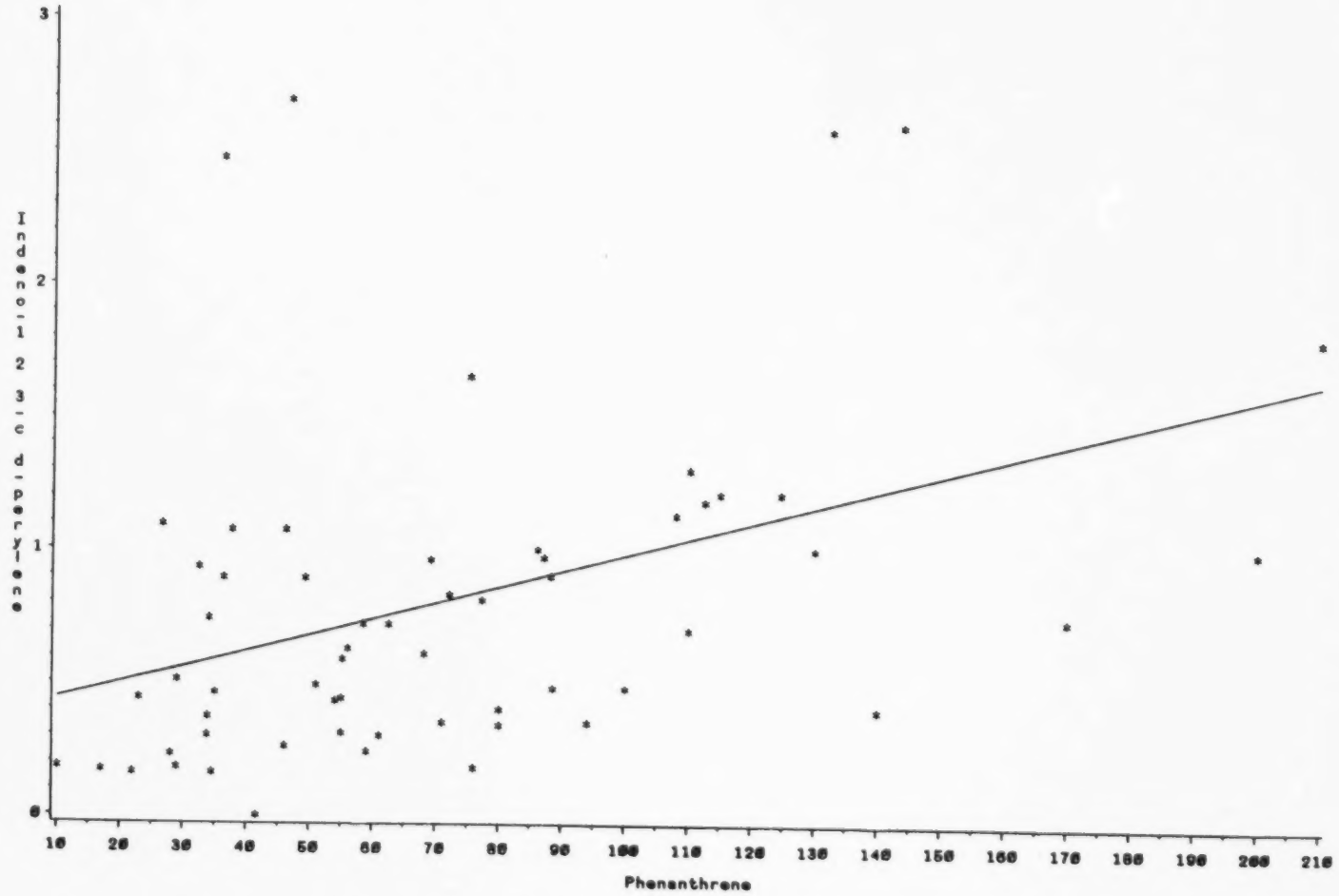


Figure D-22. Combined 1984 and 1987 Study Data for Predicting Indeno(1,2,3-c,d)perylene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

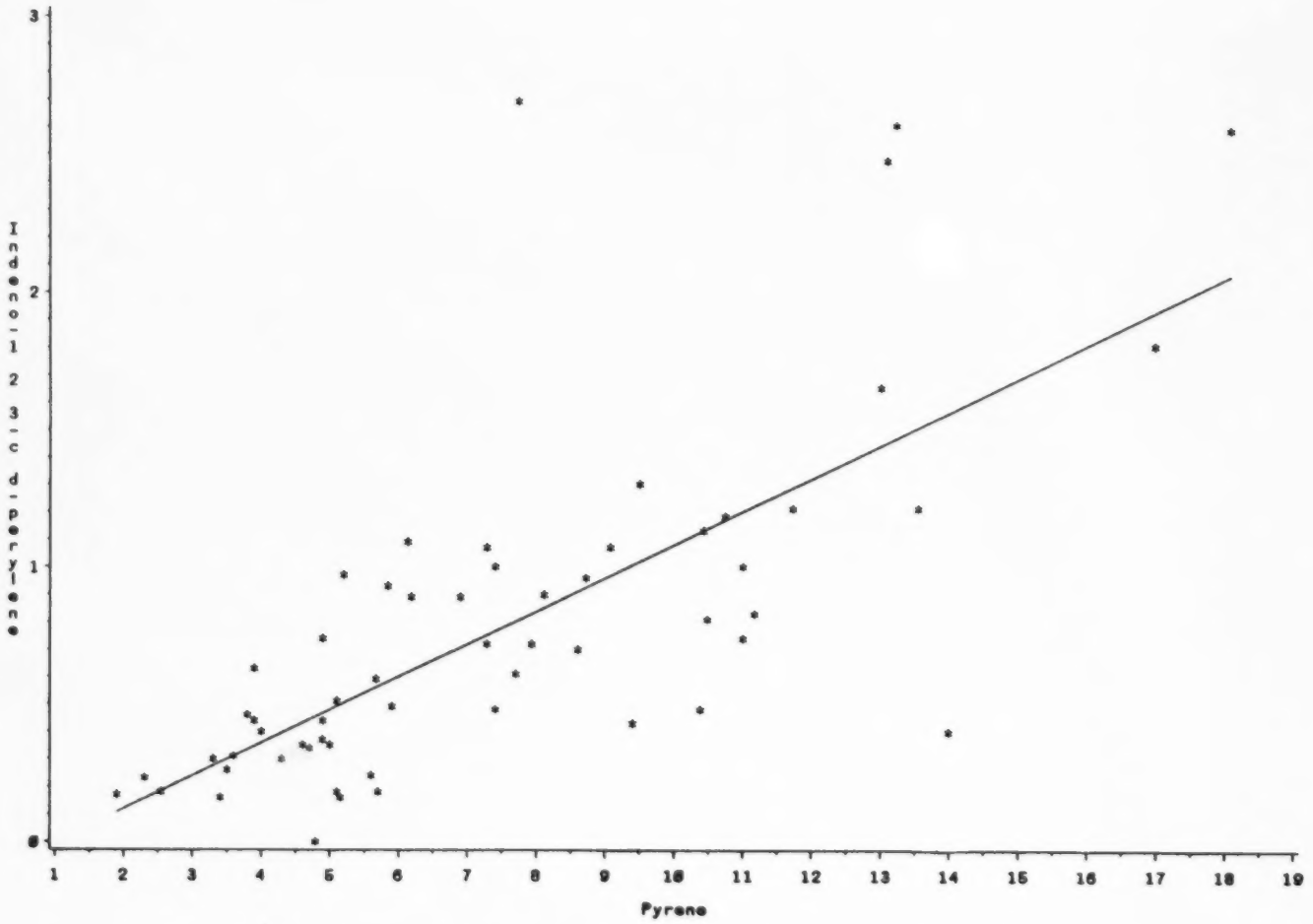


Figure D-23. Combined 1984 and 1987 Study Data for Predicting Indeno(1,2,3-c,d)perylene Concentration Levels from Measured Levels of Pyrene (ng/m3).

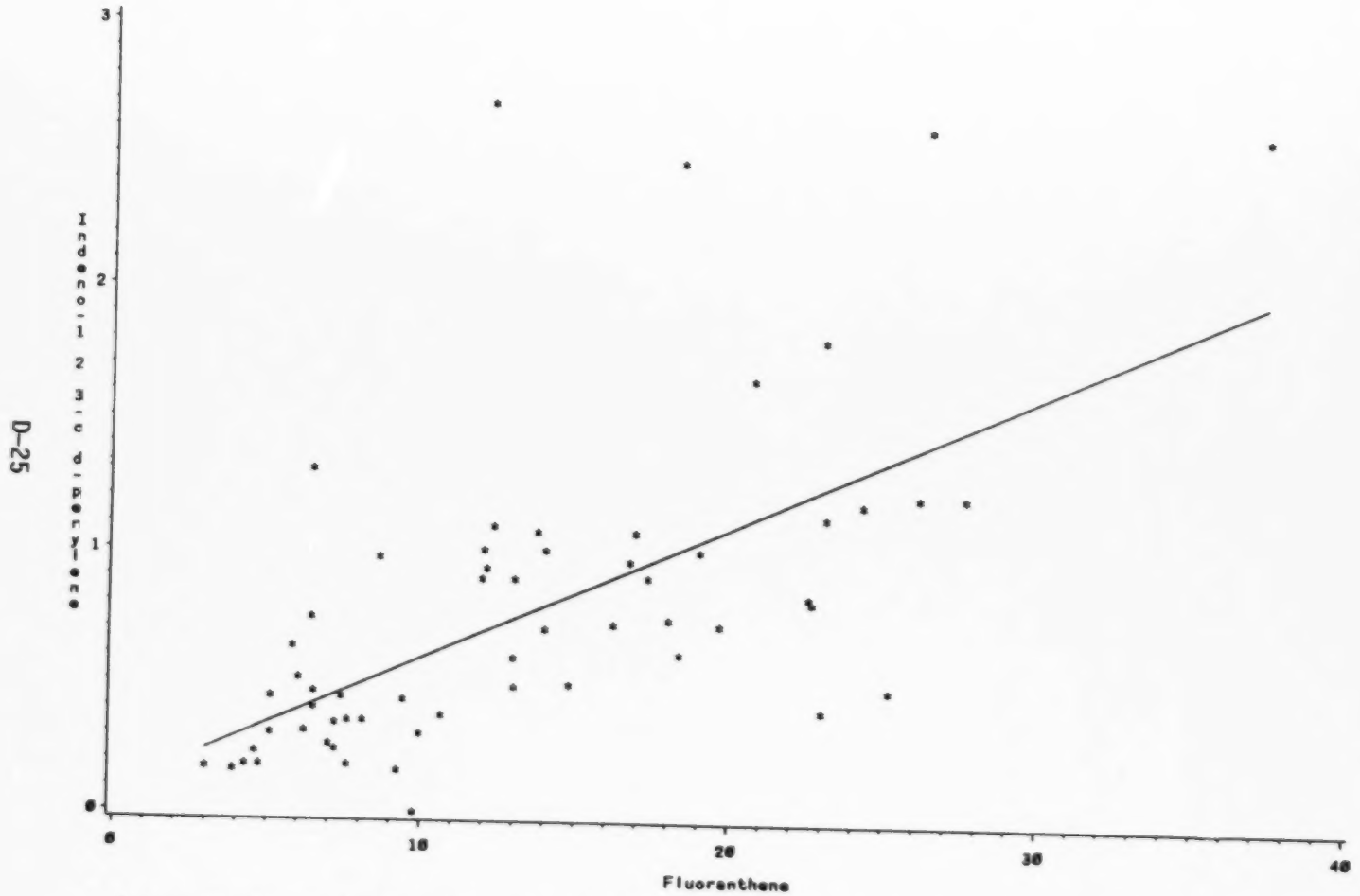


Figure D-24. Combined 1984 and 1987 Study Data for Predicting Indeno(1,2,3-c,d)perylene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

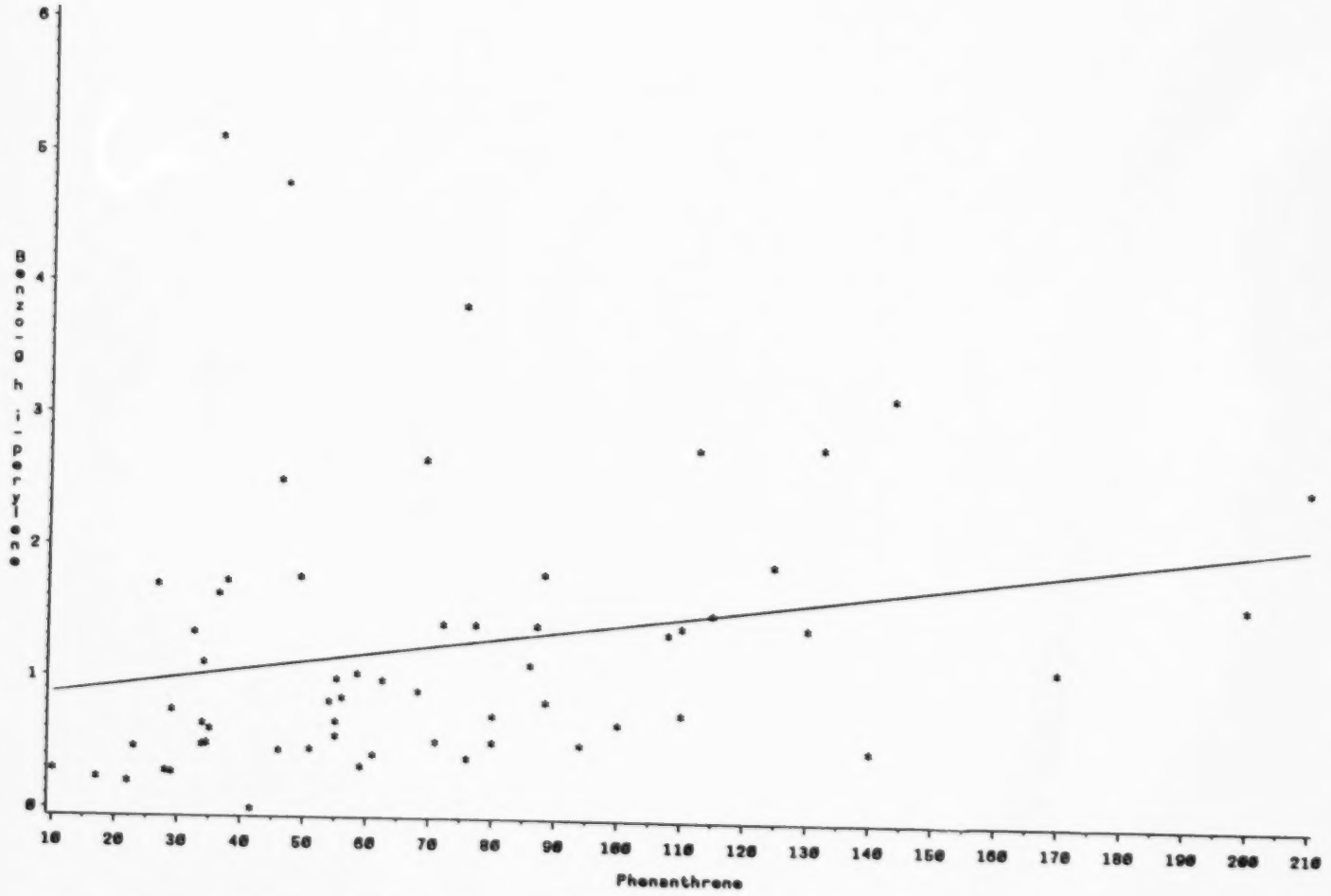


Figure D-25. Combined 1984 and 1987 Study Data for Predicting Benzo(g,h,i)perylene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

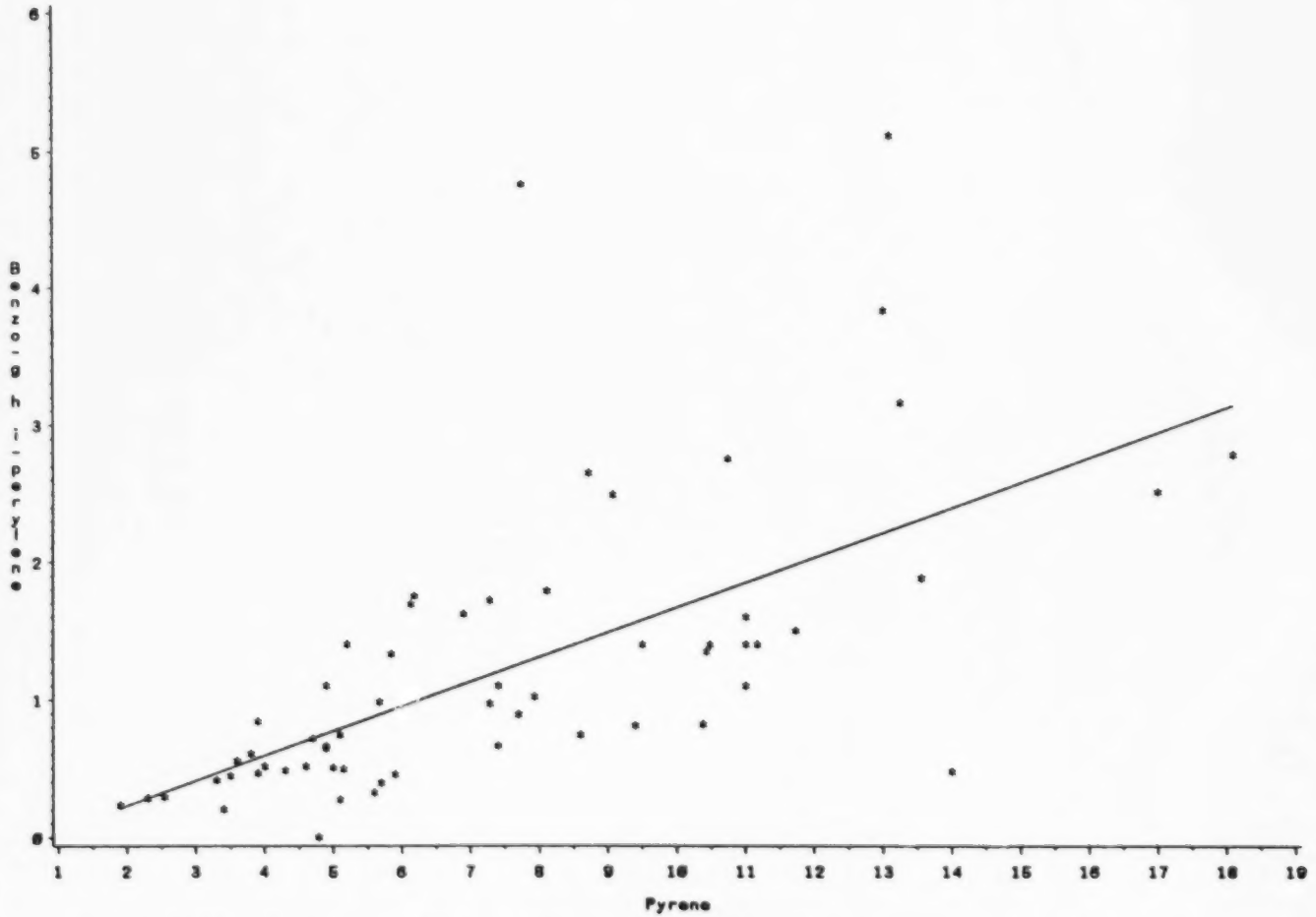


Figure D-26. Combined 1984 and 1987 Study Data for Predicting Benzo(g,h,i)perylene Concentration Levels from Measured Levels of Pyrene (ng/m3).

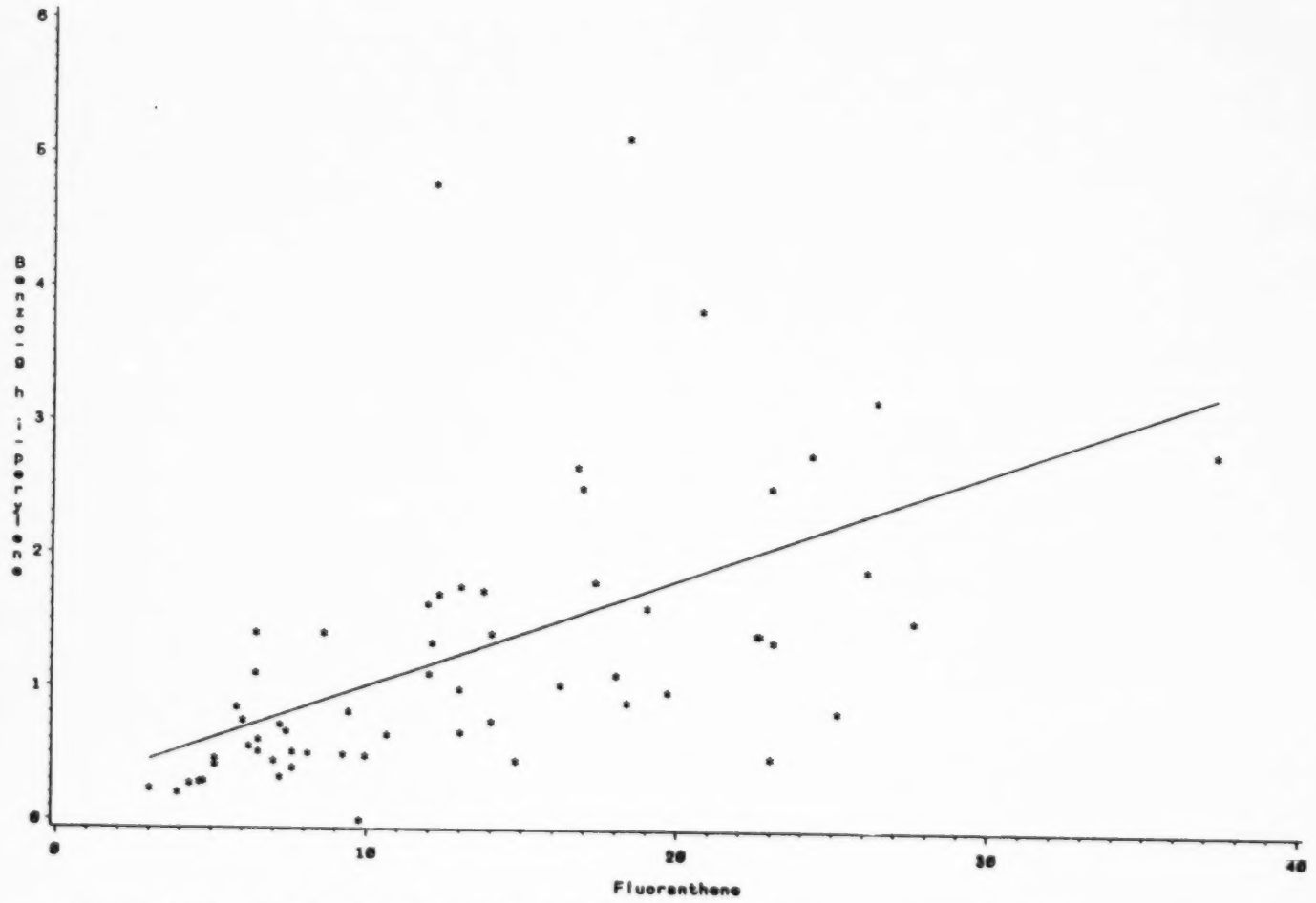


Figure D-27. Combined 1984 and 1987 Study Data for Predicting Benzo(g,h,i)perylene Concentration Levels from Measured Levels of Fluoranthene (ng/m3).

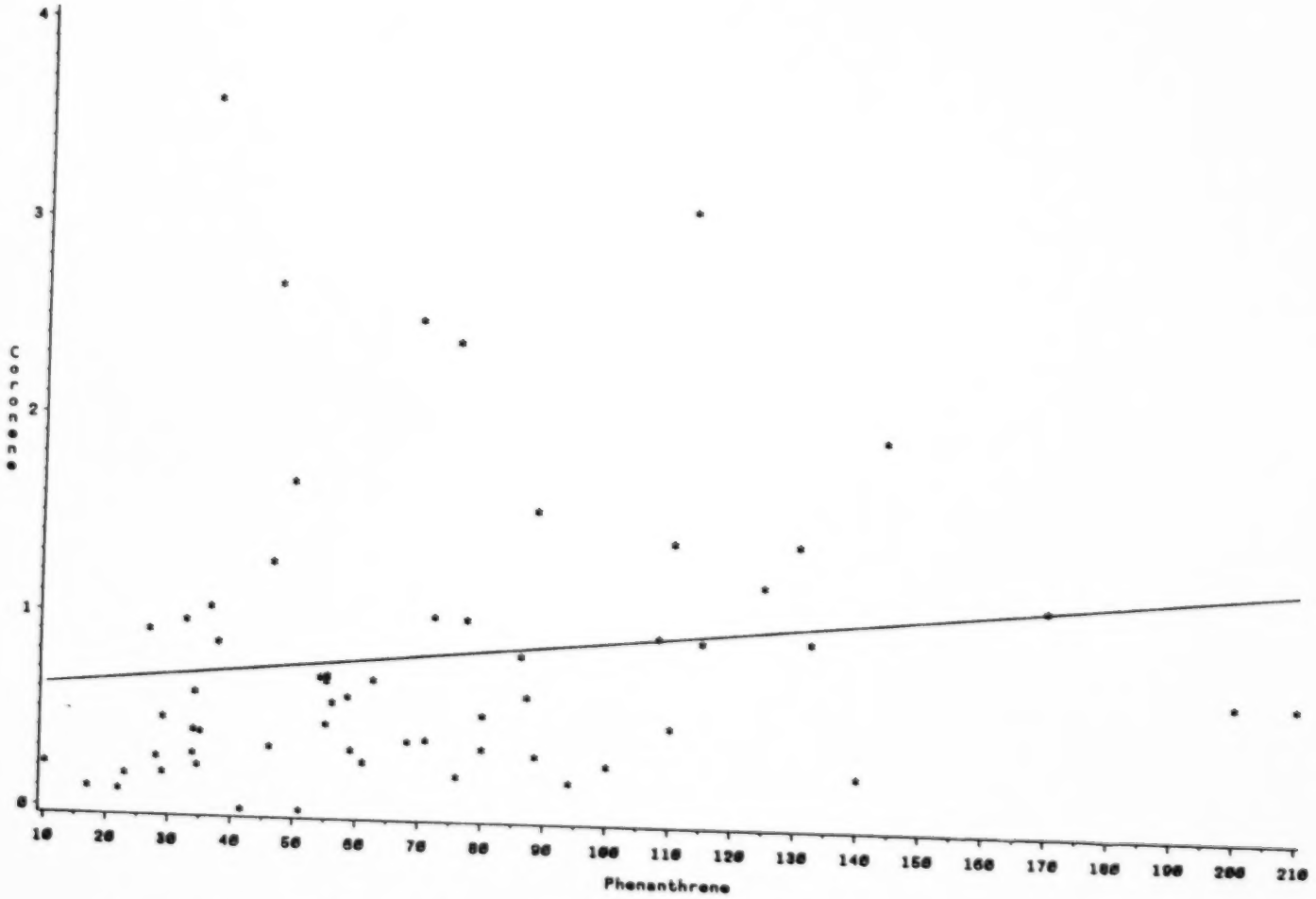


Figure D-28. Combined 1984 and 1987 Study Data for Predicting Coronene Concentration Levels from Measured Levels of Phenanthrene (ng/m3).

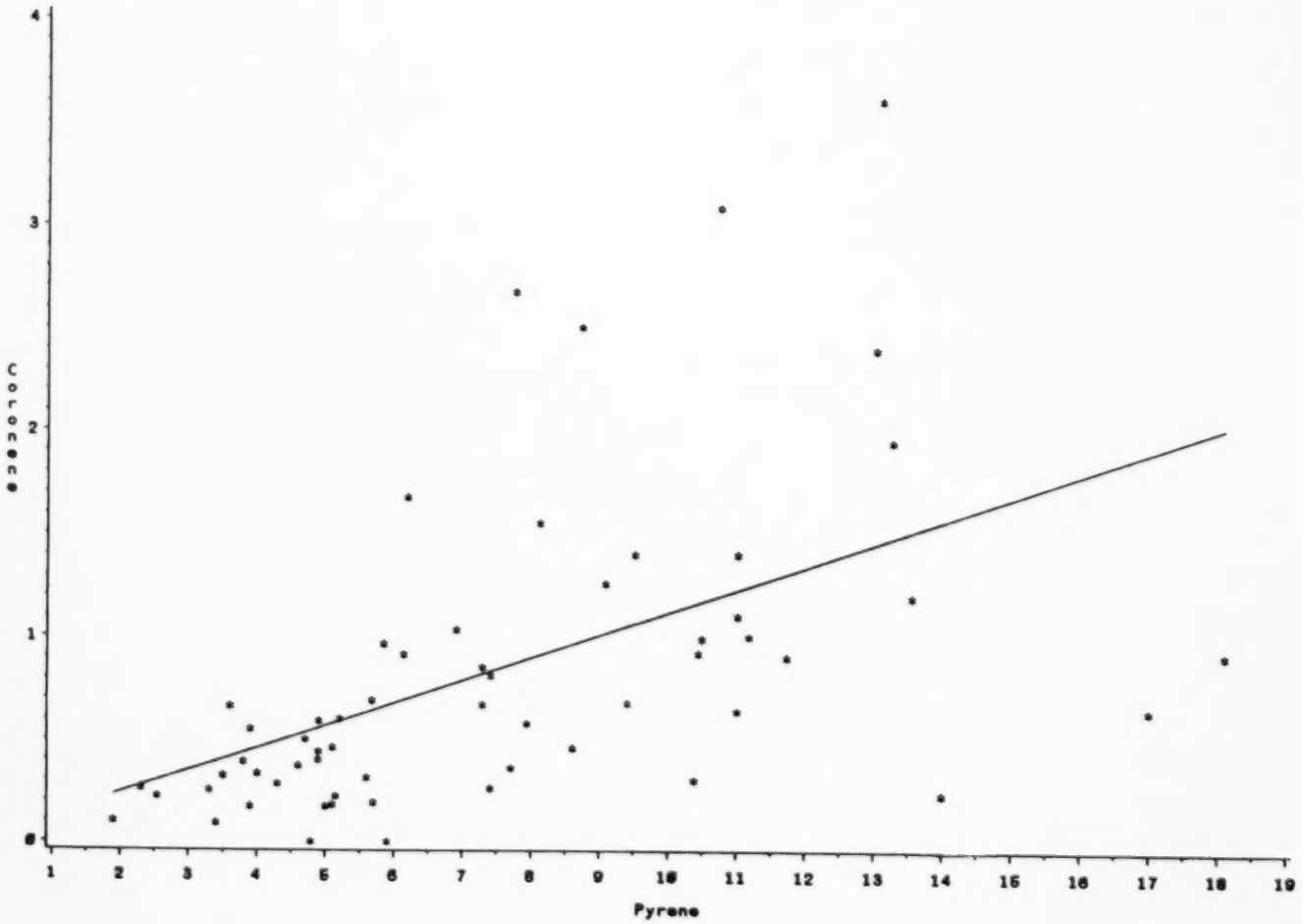


Figure D-29. Combined 1984 and 1987 Study Data for Predicting Coronene Concentration Levels from Measured Levels of Pyrene (ng/m3).

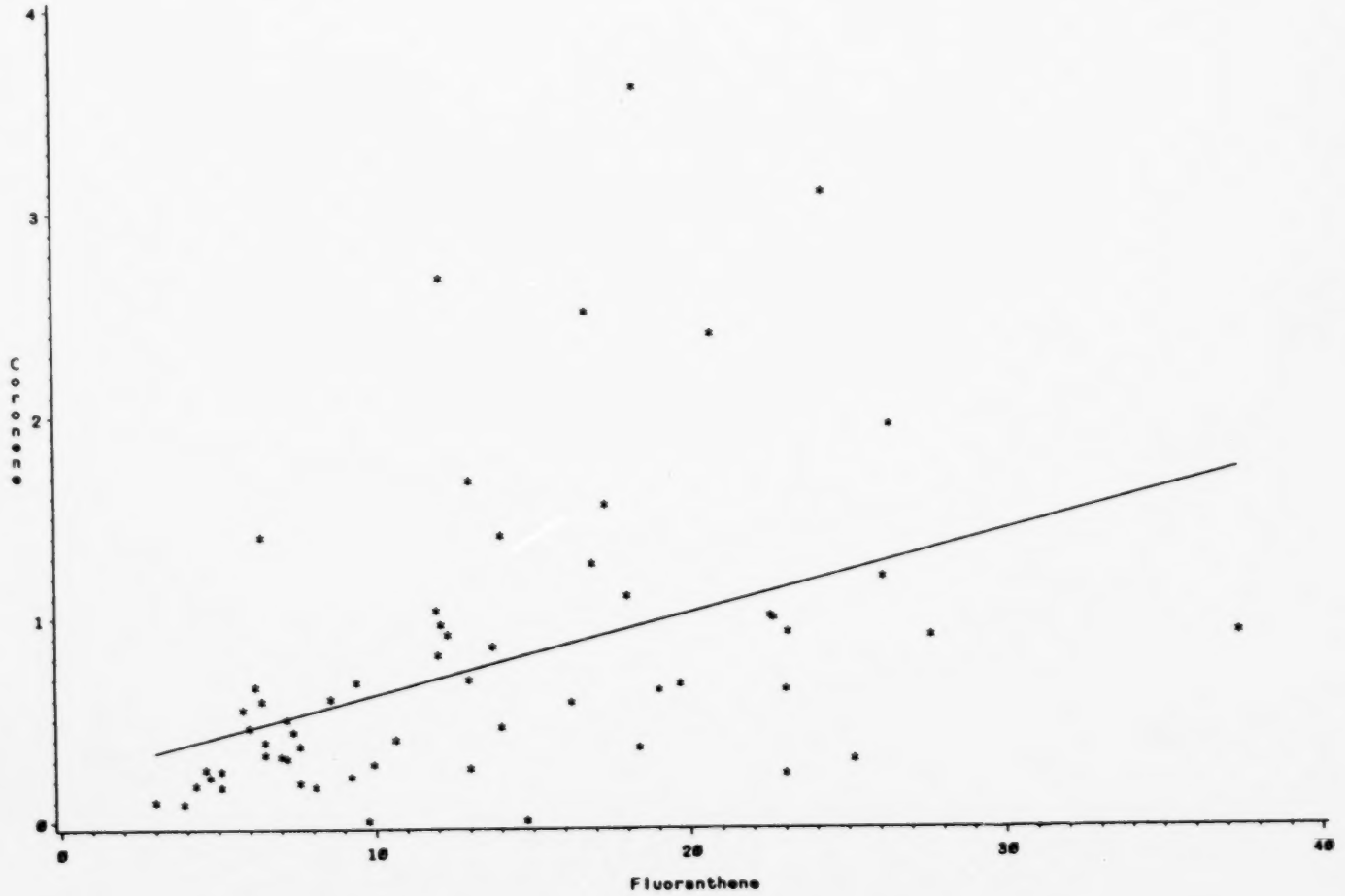


Figure D-30. Combined 1984 and 1987 Study Data for Predicting Coronene Concentration Levels from Measured Levels of Fluoranthene (ng/m^3).